Sustainable Energy Authority of Ireland

National Energy Research, Development & Demonstration Funding Programme 2018

FINAL REPORT TEMPLATE

SECTION 1: PROJECT DETAILS

Table 1.1 – Summary of Project Details

Project Title	Quantifying Light Loss Across Ireland & Identifying Patterns of Energy Use
Lead Applicant (Organisation)	Trinity College Dublin
Lead Applicant (Name)	Prof. Brian Espey
Final Report Prepared By:	Prof. Brian Espey
Total Project Duration (months)	17 months (with NCE)

Approved SEAI Funding	€73,127.89

	Name	**Organisation**
Partner Applicant(s)	Dr. Ainhoa González del Campo	School of Geography, University College Dublin
Collaborators		

Project Summary (max 500 words)
Please provide an overview of your project, the context, objectives, key results and outcomes. <u>Overview</u> This project was designed to gather basic light measurement data to produce the first quantitative review of light pollution and energy use on the island of Ireland. Data for this work comes from the combination of measurements of light output to space, coupled with colour imagery from the International Space Station and, additionally, ground-based measurements. <u>Objectives & outcomes</u> Outputs from this work provide data and results which can be used to underpin the development of solutions to energy waste in the lighting sector and which can contribute towards greater energy awareness and carbon reduction as well as reduced environmental impact. Additionally,

the results also support the development of sustainable dark sky communities through the identification of dark sky areas. Our work also feeds into the development of structured plans down to local level by identifying the origin and amount of light produced from different types of light sources, from residential to public. Additionally, the work can be used to compare light output from different lighting technologies, including LED full-cutoff lighting technology which is supported by SEAI. The data can be used as the basis for a report on the national situation, and the processed data is available for council and commercial/industrial use, as well as providing validation of our approach for future work on this topic.

The effects of future changes in lighting types (e.g. the introduction of light-emitting diodes [LEDs]) and practices (e.g. reducing the duration of lighting and/or dimming of light levels) can be directly ascertained and monitored from such data and thus guide future planning of light and energy abatement. The identification of both hotspots in energy use and also areas of best practice will help inform future discussion, and guide the areas where funding should be directed. This will aid in the development of solutions from both the public and private sectors (e.g., improved luminaire designs and installations, legislation to restrict wasteful practices) and to transition us to a more sustainable lower carbon economy.

Keywords (min 3 and max 10)	Remote sensing; light pollution; public lighting; energy efficiency; urban planning; spatial analysis

SECTION 2: EXCELLENCE & INNOVATION (max 5 pages)

2.1 Innovation / Novelty – Beyond State-of-the-Art

Describe how your project has furthered the current state-of-the-art, current knowledge or current practice. Clearly highlight the degree of novelty and innovation demonstrated by your project.

Address each innovation in a bullet point below. Add as many bullet points as you need:

- *Innovation 1: Quantitative Imagery of Light at Night in Ireland*

  Summary: We have put together the first database of quantitative measurements of both ground- and space-based light output from Ireland. Space imagery includes both quantitative radiance measurements and also colour imagery taken by astronauts and these data have been georeferenced to enable subsidiary data - such as the light output from particular towns, landuse types or regions - to be obtained and this can guide future policy decisions.

- *Innovation 2: Public lighting output*

  Summary Using the database of information obtained for this project together with the RMO-supplied public lighting database it has been possible to study the light output of historic and current public lighting types and the effect of the changeover to modern LED technology which also limits the amount of light going into space. This is the first time that such an approach has been possible.

2.2 Project Objectives

In the Table below, list all project objectives as detailed in your application, and provide on update on their status. Have these objectives been achieved? What were the key outcomes or deliverables associated with each?

Table 2.1 – Summary of Project Objectives

No	Objective Description	Objective completed (Y/N) Justify your answer	Key Outcomes/Deliverables
1.	To extract calibrated satellite imagery of Ireland from the SUOMI satellite data.	Y	Database of georeferenced intensity-calibrated satellite imagery of Ireland.
2.	To identify suitable astronaut imagery and to georeferenced and intensity calibrate those data.	Y	Database of georeferenced intensity-calibrated astronaut imagery of Ireland.
3.	To construct a cross-linked database of processed imagery for Ireland.	Y	
4.	To analyse the time-resolved data in conjunction with landuse data to identify the source and nature of the light emissions.	Y	Spreadsheets of light intensity for different Irish city landuse areas.
5.	Generation of results for presentation/publications (on-going throughout work) – 2 papers envisaged	Y – Partially complete: presentations have been given at two conferences and an international European Symposium. One co-authored paper	Engagement with DCCAE, the Road Management Office, Transport Infrastructure Ireland and local councils has been achieved. Based on

		based on this work is under review currently. Other papers are in preparation.	lobbying, the RMO initiated a comparison of LED lighting and the new procurement document was rewritten to provide a cap on the blue content of new LED lighting (i.e, CCT < 3300K).

SECTION 3: RELEVANCE & IMPACT (max 6 pages)

3.1 Relevance to the needs of the Irish Energy Sector and to SEAI

Clearly position the outcomes and impact of your project with reference to the needs of the Irish Energy Sector, national and international policy objectives, and SEAI's remit.

Economics & Energy

Our measurements of light emission illustrate the strong growth in light and energy use in Ireland and illustrate the potential for quantitative measurement down to local level on a regular basis. Light and its economic cost are relevant to the NEEAP to reduce energy consumption by identifying areas in need of attention as well as areas demonstrating best practice, and also enabling monitoring and cost assessment on a regular basis. Preliminary measurements of the light emitted from Dublin into the general environment has identified that energy equivalent to one third of that used in public lighting ends up beyond the usefully illuminated area, either in the general environment out to tens of km away or lost to space. Note that although a proportion of streetlight (≈10-15%) is unavoidably reflected from both grass or road, the remainder of the light lost is preventable, and broadly consistent with the estimate of potential improvement made by the SEAI's Public Lighting Working Group, though that figure is based on changes to lighting practices as well as installations, whereas ours is a snapshot based on the technology alone [e.g. as shown in earlier SEAI Public Lighting Working Group publications]. The factor of one third improvement in public energy consumption has been set in the Third National Energy Efficiency Action Plan (NEEAP).

Our estimate of power lost – which is a lower limit on the true amount – is calculated to be 4 MW (the capacity of a small hydroelectric plant) which equates to an energy loss of 17 GWh annually, at a cost of €2.4 million, or 8,000 tonnes of CO_2. While most of this light originates from public lighting, commercial and industrial lighting also contributes. In Dublin city centre this is manifested by an overcast sky brightness (i.e., when the energy lost to space is reflected back to the ground) that is up to roughly one thousand times brighter than the natural sky intensity. We note that the calculated light energy loss is roughly similar to that for Vienna, which has a population of 1.8 million and a similar illuminance due to diffuse light (i.e. the light energy density in mW/m^2) in the City Centre (Wuchterl, private communication – 2016). As the measured light output from Dublin is one third of the national value, the total cost can be estimated to be closer to €7 million. The estimate of energy waste is similar to that determined previously by the SEAI Public Lighting Working Group, though our estimates differ, as that estimate was based on using "trimming and dimming" – reducing both the duration and intensity of the lighting, as well as moving towards improved luminaires to restrict upwards light.

Identification and quantification of energy waste and its cost is directly relevant to the NEEAP and the National Mitigation Plan through aiding in efforts to reduce energy and carbon use on an on-going basis. The available imagery database will also aid in the identification of improvements for individual businesses.

3.2 Project Impact

Discuss the key impacts of your project: societal, economic, technological or otherwise. Clearly identify and highlight the value of your project in the wider context.

This was the first overall examination of light output and light pollution in Ireland and has provided both data and results that are of relevance to public and commercial/industrial bodies as well as lighting professionals. More generally, the results have provided quantitative data for national bodies and national and local policy makers. As an illustration we have engaged with the Department of Communications, Climate Action and Environment (DCCAE), Road Management Office (RMO) and Transport Infrastructure Ireland (TII) to aid in the assessment of lighting plans and possible improvements in both individual council areas as well as the road network nationally. This engagement has led to a changed specification for new LED lighting to a more environmentally-friendly warm white colour. We are also engaged with lighting contractor Electric Skyline which is installing dark sky friendly LED lighting to support the development of the sustainable Wild Nephin Dark Sky Park in Mayo.

Face-to-face meetings with the TII as well as the Royal Institute of Architects in Ireland have been deferred because of the Covid-19 crisis. Using our observations of light output from different lighting types and landuse areas our work can have an influence on further plans to reduce light waste through legislation. Examples of the latter are, for example, whether lighting curfews should be considered in some areas or for some uses, such as the reduction in LED advertising displays, or inner city commercial light after midnight through the reduction in lighting in shopfronts/displays. Engagement with councils, including Mayo and Kerry has provided them with expert advice on light at night and how to support the dark sky areas in both counties. Other councils are also interested in light output, and we have been approached by Monaghan CC to monitor the effect of a changeover to LED lighting at the Tullyvin Roundabout.

In terms of lighting and cultural impact, we have engaged with OPW representatives and the Meath County archaelologist to discuss current and potential lighting impacts on the Brú na Bóinne cultural site, and also helped arrange two public sky viewings (in Nov 2019 and Feb 2020) at Knowth. For this work satellite imagery provided a useful basis to study the amount and extent of lighting impact from surrounding regions.

It is also to be noted that satellite measurements also provide information on gas flares, as these data are used in a global context to monitor output from gas wells. Light from the Corrib gas field flare at Ballinaboy in Co. Mayo is visible from space, and quantification of this output may provide a useful adjunct to estimates of output appropriate to energy and climate change discussions. Engagement with the Ballinaboy management has led to the adoption of improved lighting on-site.

Finally, we have used the outputs of this work and insights gained to underpin public engagement to increase awareness of light waste and light pollution as well as actions which can be taken to reduce its level.

We are considering how best to present our results in accessible formats, whether it be maps, tables, or graphs that will enhance the utility of our work. Such outputs will be made available to SEAI and Councils in suitable format for use in databases/mapping systems, such as SEAI's Wiki Mapping Systems platform. Our results will be incorporated into a searchable database covering both historic and recent datasets so that comparisons and trends can be determined.

3.3 Communication, Dissemination and Exploitation

Please provide details of all dissemination activities undertaken throughout the project, providing references and links where applicable.

- Dissemination via. attendance at conferences by Lead Applicant-

- Artificial Light at Night 2018, 12-14 November 2018
  http://physics.utah.edu/alan2018/index.html
- Light Pollution Theory Modelling and Measurement 2019, 25-28 June 2019
  lptmm.org
- 14th European Symposium for the Protection of the Night Sky, 3-5 November 2019
  https://www.mayodarkskyfestival.ie/symposium-programme

- Interaction with stakeholders (council lighting/environmental representatives etc.) -
  - Prof. Espey chaired the 14th European Symposium for the Protection of the Night Sky, held in Mulranny, Co. Mayo, 3-5 November 2019
    https://www.mayodarkskyfestival.ie/symposium-programme
    Council presence included Peter Hynes, CEO of Mayo CC and Sarah Morgan (Planning Policy & Research Officer for Laois/Longford/Offaly/Westmeath Councils)
    Media presence included Duncan Stewart and Anja Murray of EcoEye.

    [The Symposium was mentioned in Michael Viney's Irish Times article 2 Nov 2019:
    https://www.irishtimes.com/news/environment/dim-the-lights-our-world-without-darkness-is-an-unnatural-disaster-1.4061589]
  - The Lead Applicant has arranged additional meetings with Transport Infrastructure Ireland (TII) and the Committee of the Royal Institute of the Architects of Ireland to discuss lighting reduction and the implementation of more environmentally-friendly lighting. Both of these meetings have been deferred until after the COVID-19 restrictions.
  - The Lead Applicant has had a number of interactions with Niall Roycroft, Meath and TII Archaeologist relating to the impact of lighting on the night-time environment on the Brú na Bóinne area.
  - As part of the development of a dark skies at Brú na Bóinne
  - Input to new lighting development at Wicklow Mountain Rescue post in Laragh.

- A publication during this period to which the Lead Applicant provided input and which is related to the work of this project was:
  - Fáilte Ireland "Feasibility Study for Maximising the Tourism Potential of Dark Sky Assets" (CHL Consulting Company, April 2019)

- Public dissemination –
  - 1st December 2018 - Talk given by Brian Espey to Irish Astronomical Society and the Irish Federation of Astronomical Societies (IFAS) at the "Images of Starlight" exhibition held at the Botanic Gardens, Glasnevin, Dublin. In attendance were approximately 80 members of the Irish Astronomical Society & general public.
  - 6th March 2019 – Talk given by Brian Espey entitled "Protecting the Night Sky from Light Pollution" (also the launch of the Davagh Dark Sky Park proposal) held in QUB Belfast. In attendance were approximately 40 members of the Irish Astronomical Association as well as members of mid-Ulster District Council.
  - 13th May 2020 – Talk given by Brian Espey for called Dark Sky Ireland meeting entitled "Bright Planning for The Urban Environment – The Dark Side of Illumination" at County Hall, Cork. In attendance were approximately 30 activists, including Duncan Stewart of EcoEye.

- Media dissemination by Lead Applicant –
    - also guested in a podcast for Trinity Talks Science
      available at: https://www.darksky.ie/trinity-talks-science-light-pollution-podcast/
    - most recently in videocast for International Dark Sky Week
      available at: https://www.youtube.com/watch?v=gfTsgZCLVW4

- Publications -
    - One co-authored publication with international collaborators has been submitted and is currently under review. This publication addresses the measurement of LED lighting output using space data for the US and Germany as well as Ireland and is the first such result ever reported.
    - Additional papers are currently in preparation and will be one addressing the generation of the database, the other covering analysis of the data in the context of energy and land use, particularly for the areas of Dublin, Cork, Limerick for which more detailed imagery is obtainable

- Database -
    - Data are available for an accessible database of on-line calibrated imagery hosted at TCD/UCD. Processed data in a suitable form for ingestion into mapping systems such as SEAI's Wiki Mapping Systems platform (http://maps.seai.ie/giswiki/).

      Note: This can be completed after the COVID-19 lock-down.

- An infographic and brief explanation suitable for general/media dissemination -
    - Currently being prepared

Dissemination Summary Tables

Please list details of any scientific publications in Table 3.1 on the next page. Please mention papers published in peer-reviewed journals or papers disseminated at conferences (e.g., on the conference website, etc.).

Please list details of all dissemination activities in Table 3.2 on the next page (e.g. publications, conferences, workshops, websites/applications, press releases, flyers, articles in press, videos, presentations, exhibitions, thesis, interviews etc.).

3.4 Intellectual Property Management & Exploitation

If applicable, please provide details of any patents or IP generated as a result of this research award, or patents/IP which you think may eventuate as a result of the project.

N/A

Table 3.1 – List of Scientific Publications

Title	Main Author	Journal Title	Number, Date or Frequency	Publisher	Year of Publication	Is/Will open access be provided? If you marked "will", provide an estimate of the date	Peer-reviewed (Y/N)?
Direct measurement of the contribution of street lighting to visible light emissions from urban areas	C. Kyba	Lighting Research & Technology	8 issues per year	SAGE publications, in conjunction with The Society of Light and Lighting (part of the Chartered Institution of Building Services Engineers).	2020	Will be provided. Paper currently under review (manuscript ID LRT-20-0039)	Y

Table 3.2 – List of Dissemination Activities

Type of Activity	Main Leader	Title	Date/Period	Location	Type of Audience*	Size of Audience
Scientific Conference	ALAN2018 Committee	Monitoring public lighting in Ireland: using space imagery and lighting inventories	12th – 14th Nov 2018	Snowbird, Utah	Scientists & Activists	over 100
Scientific Conference	LPTMM19 Committee	Categorisation and quantification of the sources of artificial light at night from Ireland	25th – 28th June 2019	Zselic, Hungary	Scientists & Activists	50
Public Talk	Irish Astronomical Society	Images of Starlight	1st December 2018	Botanic Gardens, Glasnevin, Dublin	Members of the Irish Astronomical Society, the	80

					Irish Federation of Astronomical Societies (IFAS) & general public	
Public Talk	Brian Espey	Protecting the Night Sky from Light Pollution – also the launch of the Davagh Dark Sky Park proposal	6th March 2019	Belfast	Members of the Irish Astronomical Association, members of mid-Ulster District Council	40
Conference	Dark Sky Ireland	"Bright Planning for The Urban Environment – The Dark Side of Illumination"	13 May 2019	County Hall, Cork	Scientific Community, Civil Society, Policy makers, Activists	30
Conference	Brian Espey / Georgia MacMillan (Mayo Dark Skies)	14th European Symposium for the Protection of the Night Sky	3-5 November 2019	Mulranny, Co. Mayo	Scientific Community, Civil Society, Policy makers, Activists, Media	102

**Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).*