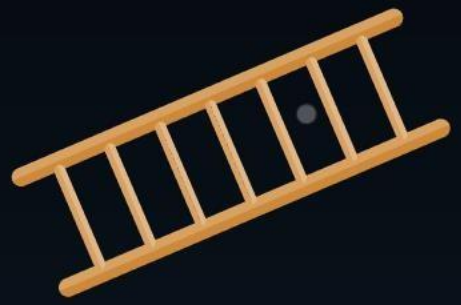


Objectives

Main Objective:

- To analyze the level of light pollution using RS & GIS techniques and devise local strategies to reduce light pollution in Eindhoven City.

Sub-Objectives:

- To study the radiance levels of Eindhoven using RS and Earth observation techniques
- To study the relation between the radiance and land use categories and identification of land use contributions to light pollution.
- To figure out the level of energy consumption by the street lights.

Project linkages to Dutch national policies

The Dutch Energy agreement 2013

- To improve annual average energy efficiency by 1.5% by 2020.

- Total GHG emissions in 2015 was 202 Tg CO2. Energy Report 2016 set to reduce emissions by 49 percent by 2030.

GHG Emissions

METHODOLOGY

OBJECTIVES

- MAIN OBJECTIVE
- SUB OBJECTIVES

LITERATURE

- FACTS/STATS
- CAUSES/TYPES/ EFFECTS

DATA SOURCES AND COLLECTION

- OVERVIEW OF RELEVANT R.S. TECHNIQUES
- STEETLIGHT DATA

DATA PROCESSING & CASE AREA

- LINKAGES OF THE PROBLEM FROM GLOBAL TO LOCAL SCALES
- DERIVE CASE AREA, VIIRS 2019

LAND USE ANALYSIS

- ZONAL STATISTICS
- TRENDS IN LAND USES, 2012, 2016, 2019

ENERGY CONSUMPTION ANALYSIS

- ANAYSIS ON STREET LIGHTS NETWORKS
- ENERGY WASTAGE ANALYSIS

SOLUTIONS AT LOCAL LEVEL

- POLICY LEVEL REGULATIONS
- SMART LIGHTING STRATEGIES

Concept of Light Pollution

- Light pollution refers misused light resulting from an inappropriate application of exterior artificial lighting products which degrades the natural light in the environment.

Why is light pollution a global problem?

- Affects 80% global population
- Consumes 19% of global electricity usage.

(Source: BBC Online Report, 15 April 2020)

Causes

It is a side-effect of three global processes including;

- Urbanization
- Industrialization
- Modernization

Impacts

1.Energy consumption
2. Health
3.Ecosystems

- Image A represents a situation with no artificial illumination
- Image B: Three sodium-vapor lamps of the 'globe type' (no shielding towards the sky) are installed and alter considerably the night sky. The light is not focused and wasted into all directions
- Image C shows a well planned alternative where the three lamps are well shielded towards the sky. They send their light only to the area to be lit

Monitoring of light pollution by Remote Sensing / GIS

Comparison data between sources

SPECIFICATIONS	NIGHT-TIME SATELLITE IMAGES		NIGHT-TIME AERIEL IMAGES	GROUND SURVEY
	DMSP-OLS	VIIRS-NPP		
CATEGORIZE SOURCE ?	NO	NO	YES	YES
QUANTIFY SOURCE?	YES	YES	YES	YES
ACCESSIBILITY	EASY	EASY	HARD	VERY HARD
TIME SCALE	1992-2013	2012 ONWARDS	--	--
TIME RESOLUTION	ANNUALLY	MONTHLY/ANNUALLY	FLEXIBLE	FLEXIBLE
SPATIAL SCALE	GLOBAL	GLOBAL	LOCAL	LOCAL
SPATIAL RESOLUTION	2.7km	750 m	ABOUT 1m	10-50cm
WAVELENGTH	0.4-1.1µm	0.7µm	--	--
BANDWIDTH	--	0.4 µm	--	--
SWATH WIDTH	3000 km	3000 km	--	--
REVISIT TIME	0.5 days	--	--	--

- The sources of light pollution through remote sensing can only be categorized through Night-time Aerial images and Night-time Ground surveys through light sensing instruments.
- Restrictions on UAV night-time aerial images capturing may be applicable according to local byelaws and other constraints may apply.

- **Limitation of Remote Sensing / GIS tools**
  - More CITIZEN SCIENCE Projects needed.
  - Integration of values from different instruments(ground based, Sky Quality meters etc. on geographic scale.

- **Limitation of Remote Sensing / GIS tools**
  - The data is related to light emissions but shouldn't directly be related to energy consumption, community wealth etc.
  - The spatial resolution of satellite images are not suitable for smaller areas/neighbourhood scale.
  - Also lighting sources such as street lights can not be identified from satellite sources providing night-time data.
  - The monthly data of VIIRS-NPP has data gaps thus annual composite values are considered for further analysis.
  - The temporal resolution of satellite images does not allow flexibility in analysis .
  - Restrictions on UAV aerial images capturing may be applicable according to local byelaws and other constraints may apply.

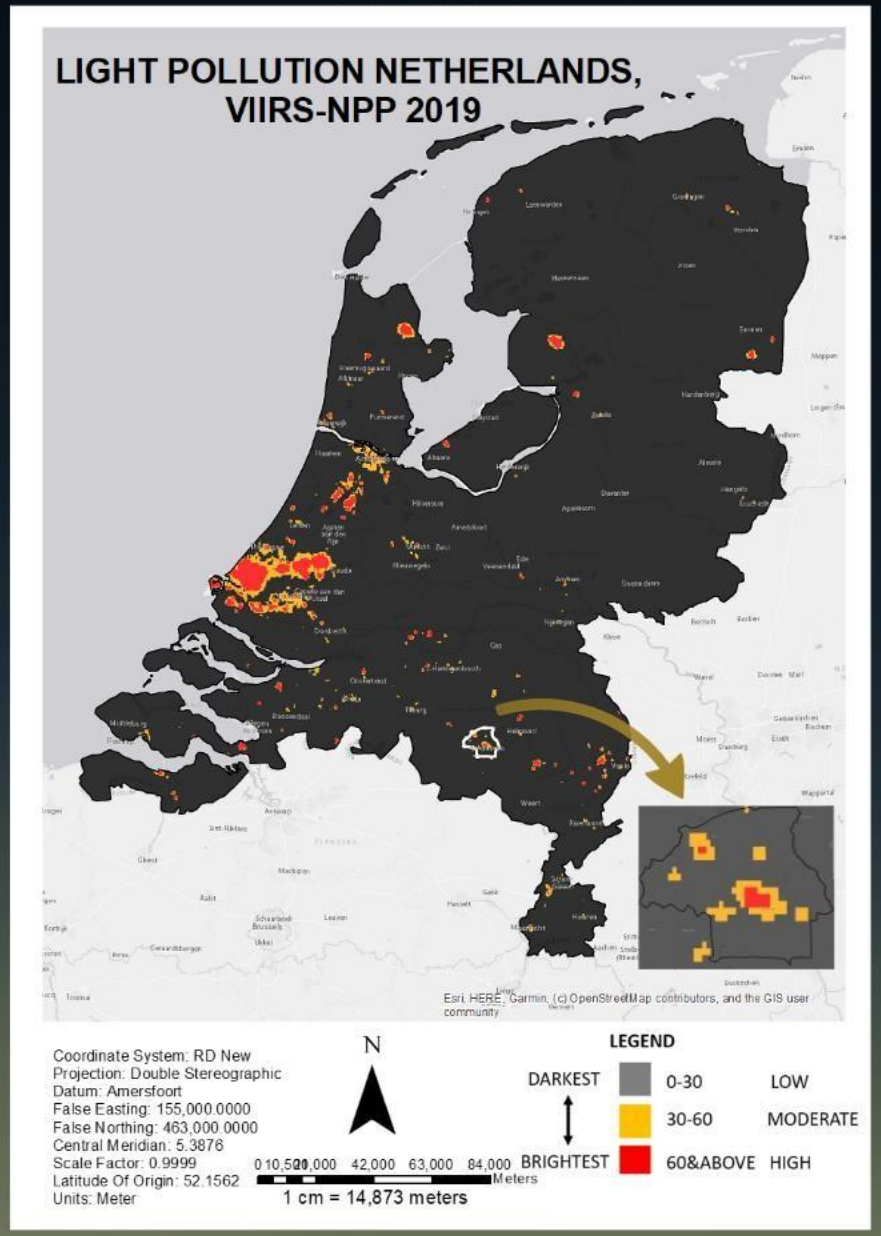
Linking global problem to local scenario

Global → National → City

NETHERLANDS RANKING IN GLOBAL LIGHT POLLUTION:

YEAR	RANK
2013	11
2014	8
2015	12
2016	12
2017	11
2018	12
2019	12

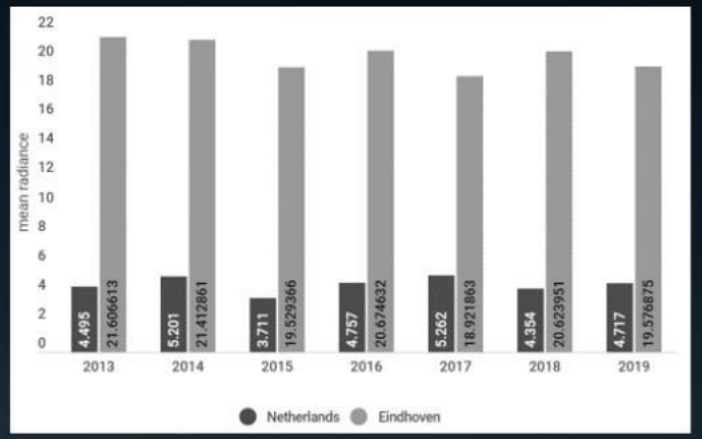
In terms of the mean radiance per pixel from VIIRS image, the Netherlands ranked about 11 among the 218 countries in the world during the current years, which reflects a high level of light pollution in the country scale.



Criteria

Cities with

- HIGHEST RADIANCE
- HIGHEST POPULATION
- DATA AVAILABILITY
- EINDHOVEN, HIGHEST IN RADIANCE,
- 5TH HIGHEST IN POPULATION



COMPARISION VIIRS2019:EINDHOVEN VS NATIONAL LEVEL

For years between 2013-2019, the mean radiance at city level is found to be approx. 4 times the national average.

- PERIPHERIES ARE EXCLUDED WHILE CHOOSING STUDY AREA SINCE ABNORMAL RADIANCES ARE RECORDED DUE TO POSSIBLE DEFENSE AREAS, NAVAL PORTS, LARGE PRODUCTION AND MANUFACTURING UNITS etc.

ABOUT "THE CITY OF LIGHT" : EINDHOVEN

Demographics

- Municipality: 231,469(5th largest in NL).
- Technology and Design Hub. Best in patent intensity in OECD region, 2008.
-
- 3rd Spot Amongst TOp 25 European cities and regions of future, Financial TIme 2014.

Relevance for further analysis

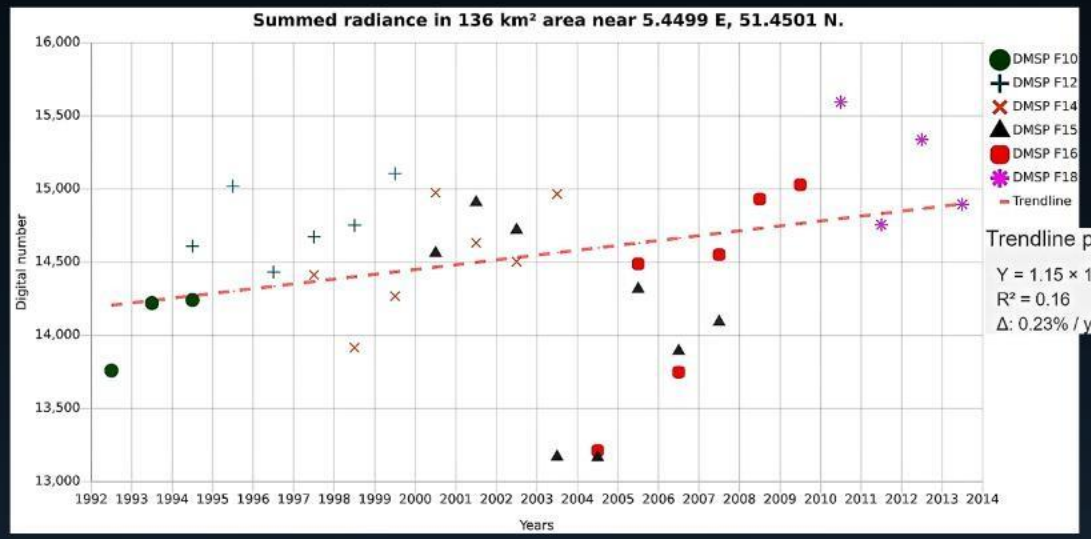
- Home to Philips(1891), world largest lighting company. Also, Philips Light Tower, Light Art Museum and other light related museum.
- Old Philips factory complex has been transformed to multipurpose cultural and residential complex called Strijp-J experiments with LED lights.
- Several other projects involving lighting up of city buildings.
- Hosts light festival GLOW in November.
- In 1997, Philips moved its global headquarters to Amsterdam
- Philips Lighting, Philips Research, Philips Semiconductors and Philips Design continue to be located in Eindhoven.

ANIMATION: CHANGE DETECTION EINDHOVEN, VIIRS 2012- 2019

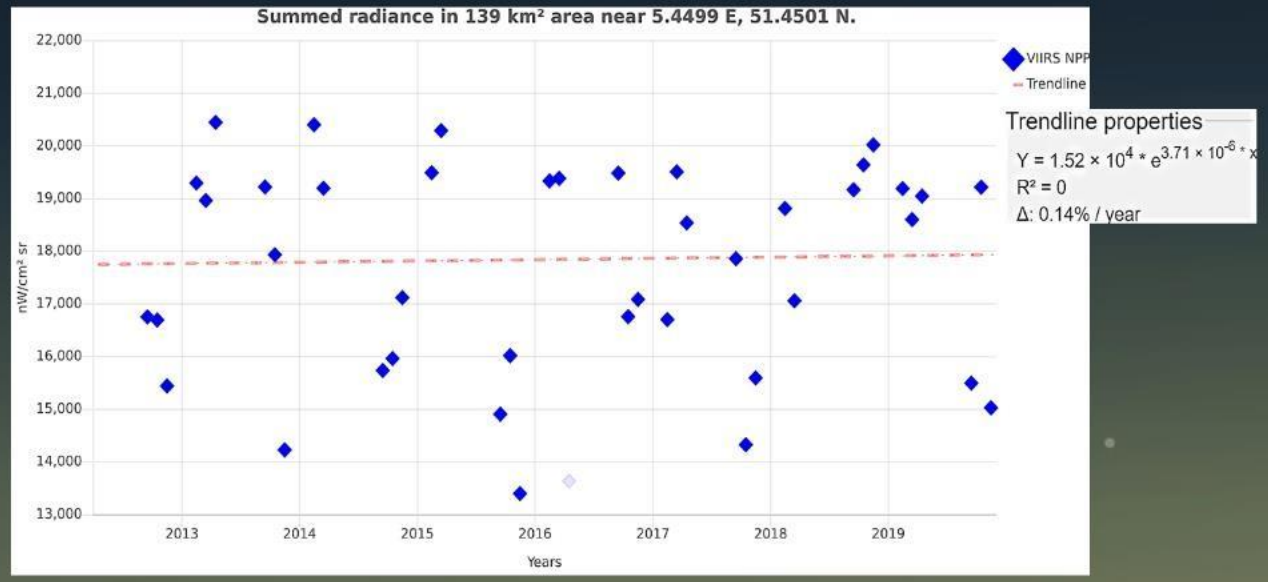
- Time delay for every change in frame: 1.5 seconds
- Rendering of video might cause lag on web platform.

SATELLITE DATA ANALYSIS FOR EINDHOVEN

RAW DMSP DATA, 1992--2013:



VIIRS DNB DATA, 2012--2019:



DMSP

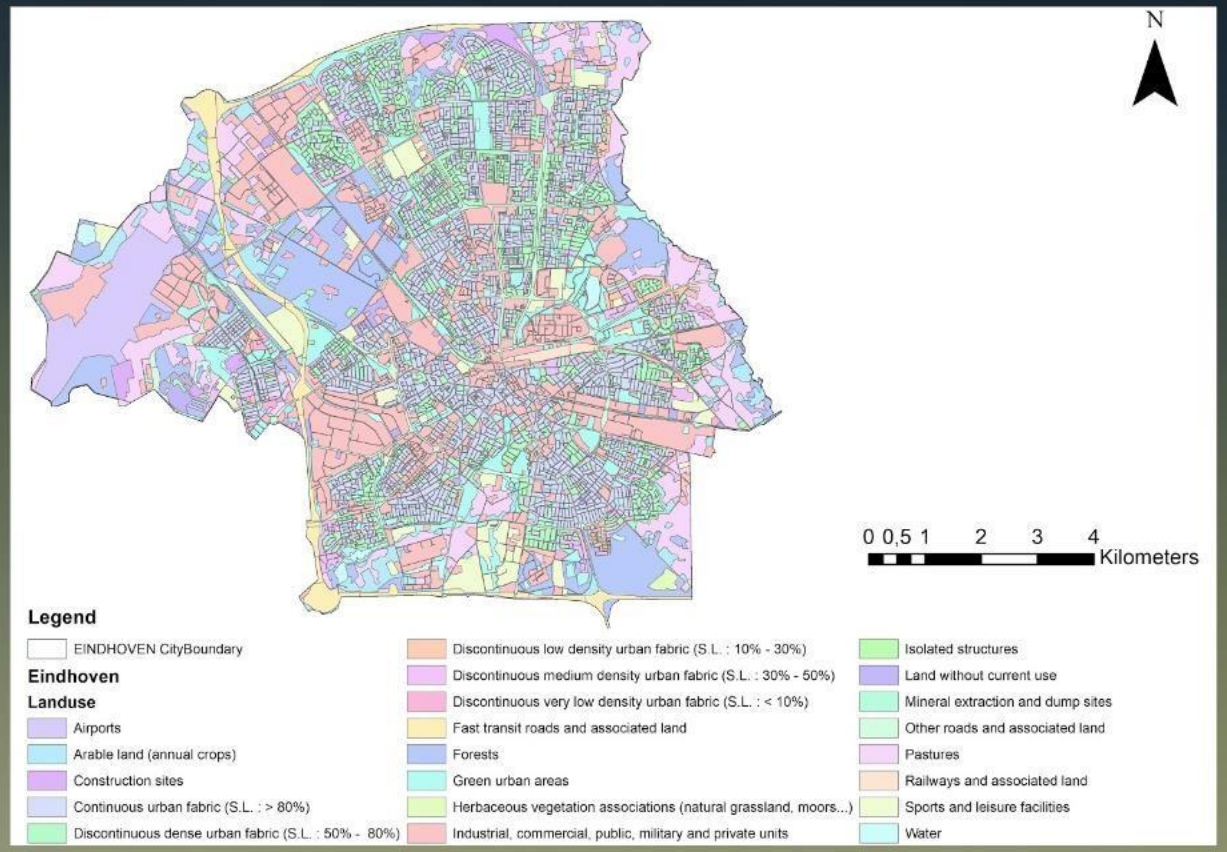
- Instrument was not radiometrically calibrated since observing night lights was not the primary purpose.
- The digital numbers ranges from 0-63 and sensors does not record precise values above 63 for example in city centres.
- The change from 1992-2013 is recorded as 0.23% per year where the data model can explain 16% of the variation in values.

Both the instruments have some important differences thus the data from 1992-present is not continuous.

VIIRS

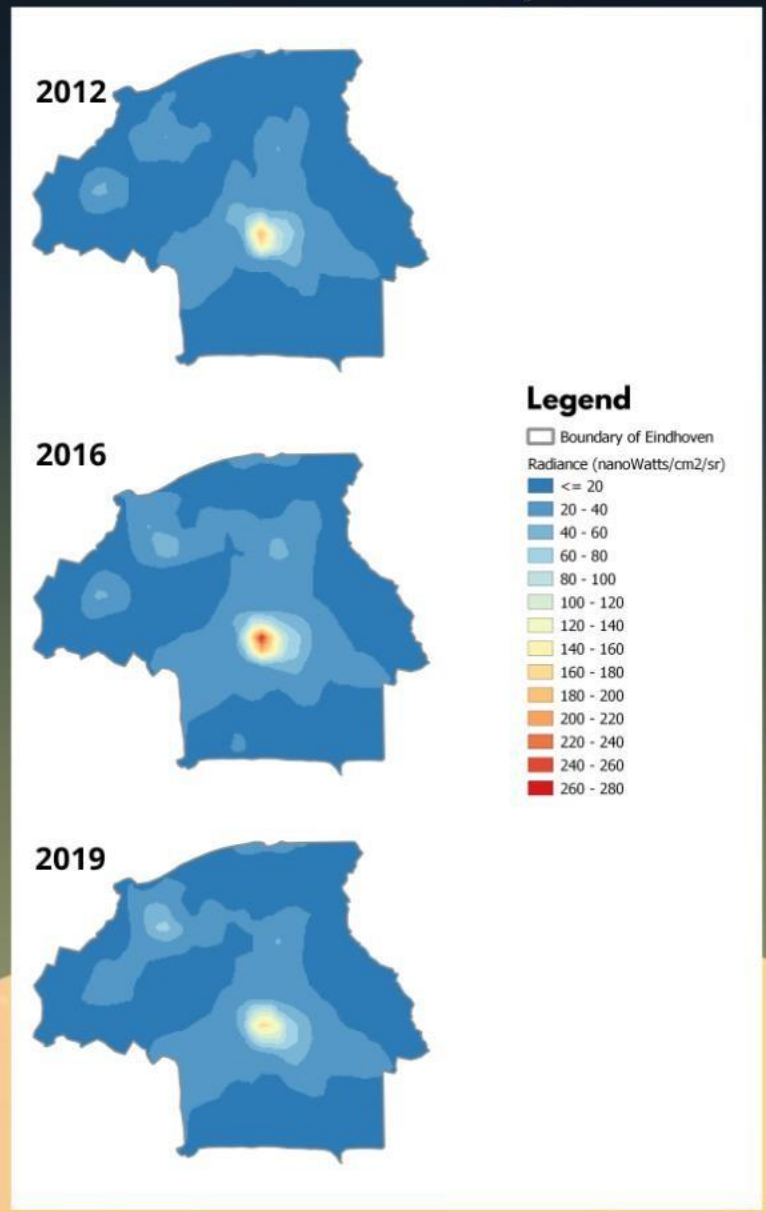
- First satellite instrument intentionally designed to image human lights on the worldwide scale.
- Major improvement over DMSP-OLS.
- The change from 2012 to 2019 is around 0.14 % per year.

Landuse map Eindhoven

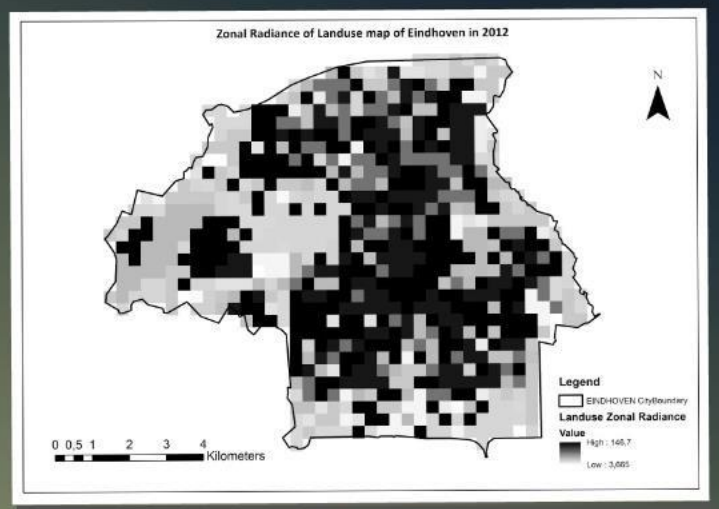


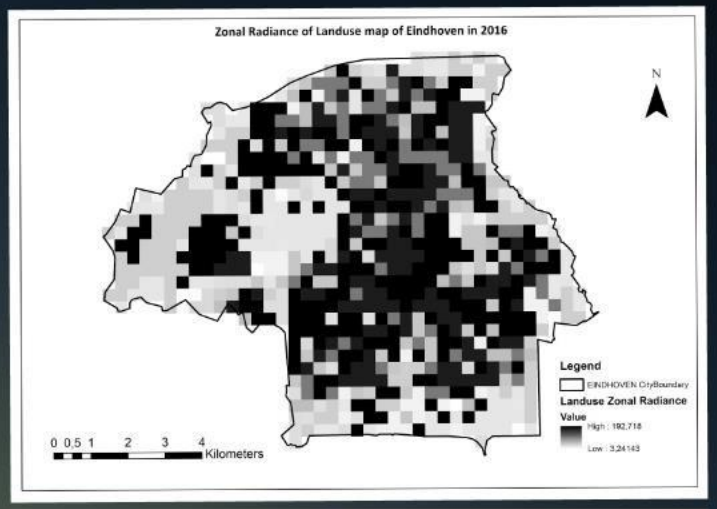
Source: land.copernicus.eu

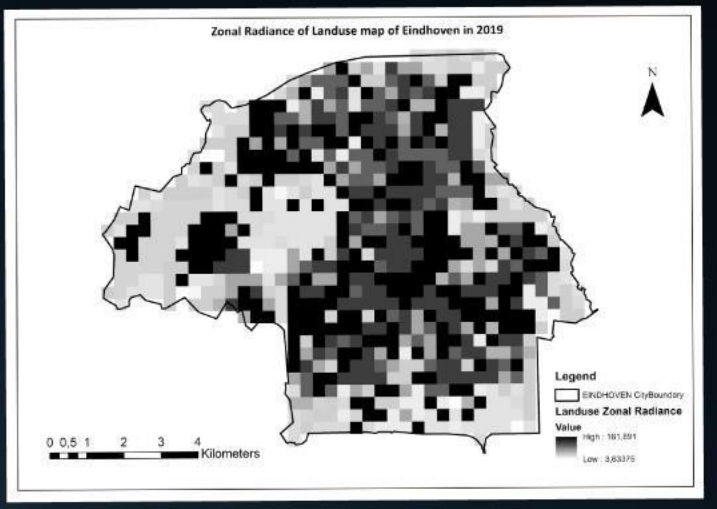
Radiance Maps



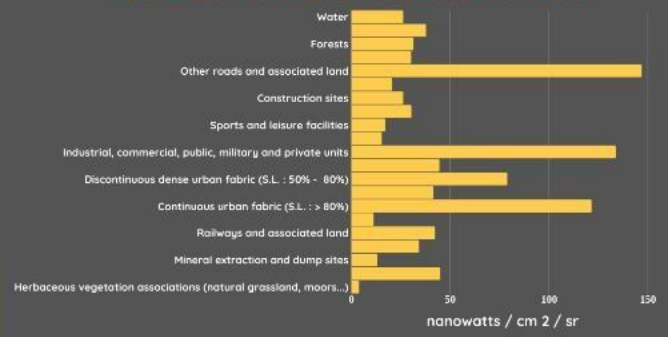
The landuse data has been associated with the radinace maps of Eindhoven using zonal statistics tool in Arcmap to produce the radiance of each land use category. The results are follows in the next slide.





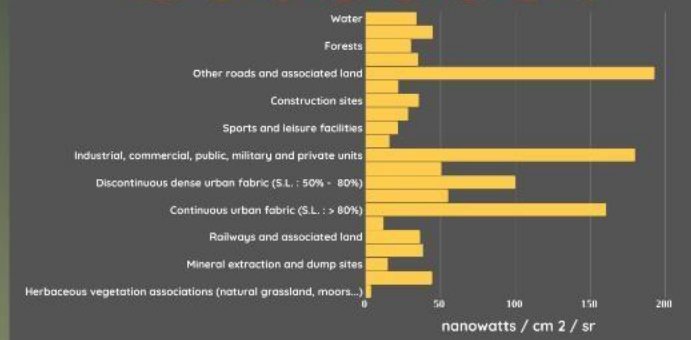


2012



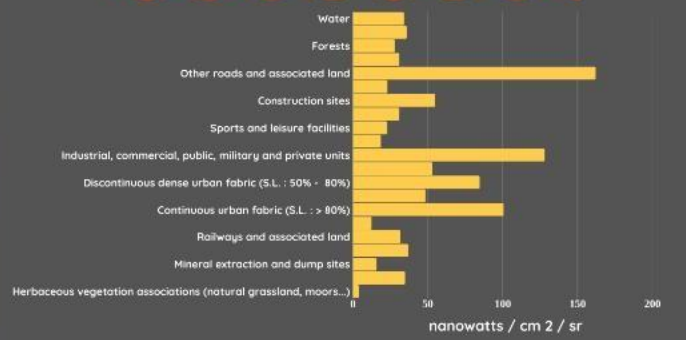
Other roads and associated land : 146.70 nanowatts / cm 2 / sr
Industrial, commercial, public, military and private units : 133.55 nanowatts / cm 2 / sr
Continuous urban fabric (S.L. : > 80%) : 121.39 nanowatts / cm 2 / sr

2016



Other roads and associated land : 192.72 nanowatts / cm 2 / sr
Industrial, commercial, public, military and private units : 179.68 nanowatts / cm 2 / sr
Continuous urban fabric (S.L. : > 80%) : 160.32 nanowatts / cm 2 / sr

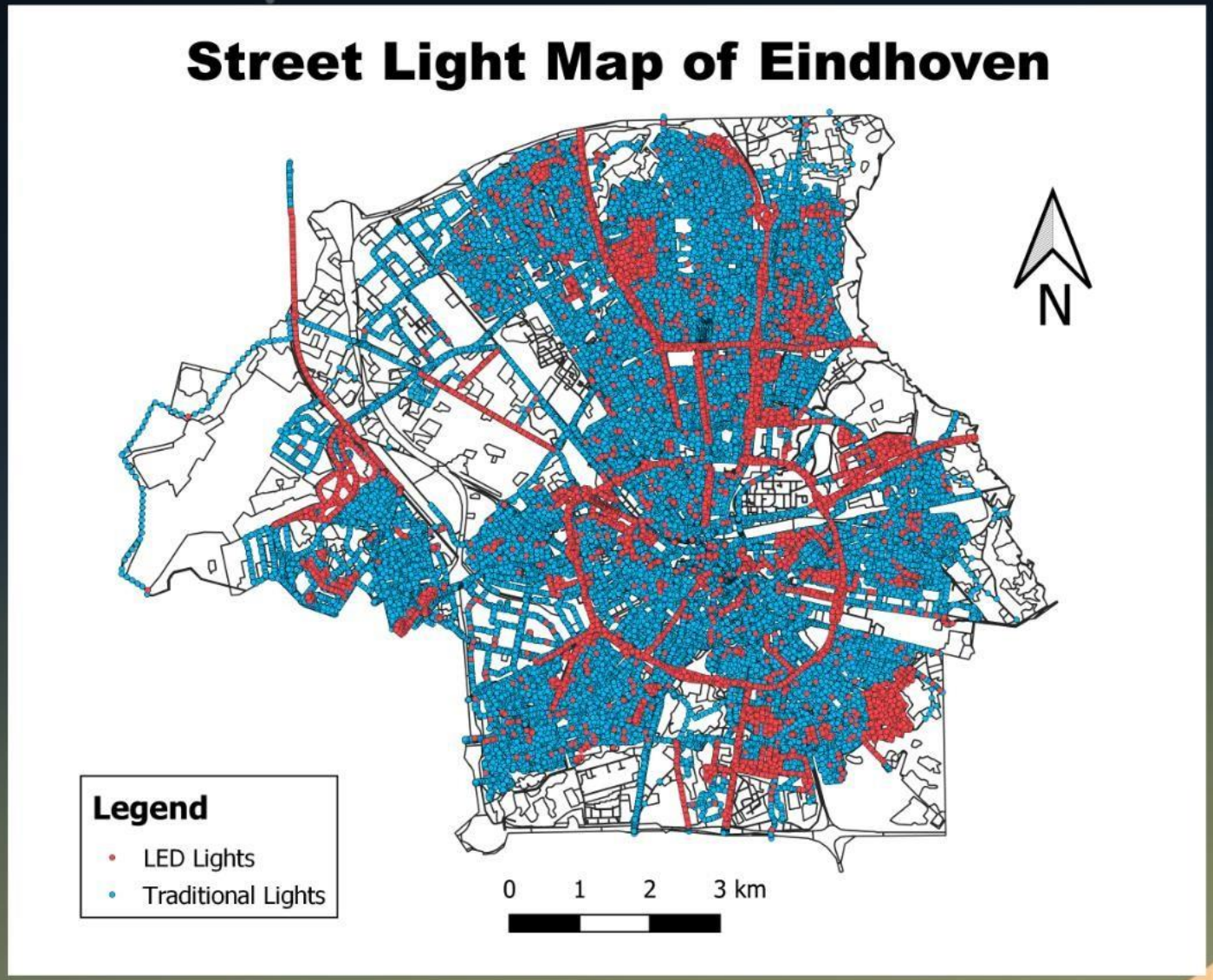
2019



Other roads and associated land : 161.90 nanowatts / cm 2 / sr
Industrial, commercial, public, military and private units : 127.93 nanowatts / cm 2 / sr
Continuous urban fabric (S.L. : > 80%) : 100.35 nanowatts / cm 2 / sr

- **From the above maps, the light pollution levels, from the year 2012 got raised till the year 2016. But from the 2019 light pollution map, the reduced light pollution levels acts as a proof of initiatives and efforts of Eindhoven municipality in reducing the light pollution**
- **Finally, the land use under roads, shows the highest share of light pollution among the other landuse classes, leading the study focus on street lights which are responsible for highlight pollution levels and energy wastage**

Energy wastage calculation from the street lights



Total No. of streetlights in Eindhoven

78,437

Energy saved by using LED instead of traditional lights

3,038 kWh

Solar Panels needed to generate the energy saved

±8,600

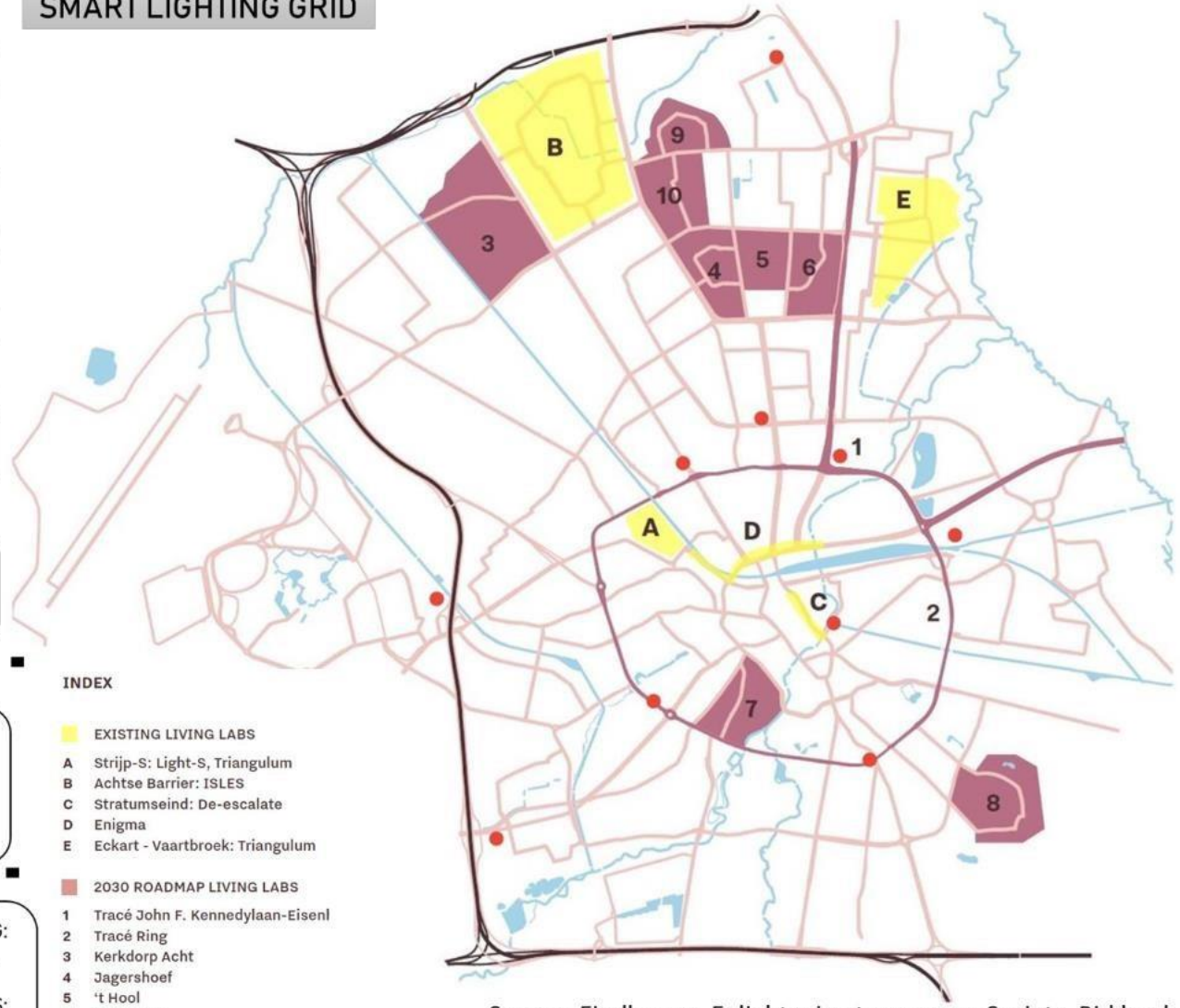
Reference: Openbare verlichting in Eindhoven (https://data.eindhoven.nl/)

LIGHTING STRATEGY AND WAY FORWARD

ROADMAP

2012	ROAD MAP URBAN LIGHTING 2030
2013	E3 SLIM PROJECT
2014	TENDERING PROCESS
2015	RECEIVING BID+ ANNOUNCING WINNER
2016	CONTRACT SIGNED BY PHILIPS
2017	STARTED INSTALLATION SMART LIGHT GRID
2020	LIGHT EMITTING DISPLAYS, SERVICE ORIENTED LIGHTING SOLUTIONS
2025	• ADAPTIVE SOLUTIONS • MODULAR SYSTEMS • SELF SUSTAINING SYSTEMS
2030	• NATURAL LIGHTING: MULTISENSORIAL EXPERIENCE • INVISIBLE SYSTEMS: ADAPTIVE, INTELLIGENT

SMART LIGHTING GRID



INDEX

EXISTING LIVING LABS

- A Strijp-S: Light-S, Triangulum
- B Achtse Barrier: ISLES
- C Stratumseind: De-escalate
- D Enigma
- E Eckart - Vaartbroek: Triangulum

2030 ROADMAP LIVING LABS

- 1 Tracé John F. Kennedylaan-Eisenl
- 2 Tracé Ring
- 3 Kerkdorp Acht
- 4 Jagershoef
- 5 't Hool
- 6 Vlokhoven
- 7 Schrijversbuurt
- 8 Gijzenrooi
- 9 Blixembosch-West
- 10 Woenselse Heide (West)

Location Airboxes AiREAS

Source: Eindhoven, Enlightening tomorrows Society, Bid book

Recommendations

- Development of a database with real time light pollution levels at local scale can be developed for monitoring purposes and rising awareness among the individuals.

- Light pollution is directly related to activities based on our land use analysis, extra care needs be taken in nightlife public activities and implementing strict rules in managing and better organization of these activities.

Strategies to tackle public Light pollution

- Replacement of CFL bulbs to LED bulbs along with some local actions such as smart lighting system adaptations, strict rules on artificial lighting (Direction of focus), etc.

In conclusion, Remote sensing can play a vital role in analyzing the trends and patterns of light pollution and acts as a base for decision making and local actions.