Selection of RE generation technologies and ES systems

CEDR 2019 Renewable Energy in Road Infrastructure
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CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

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** More than 200 references used for the development of the deliverable.*

Supporting the implementation by NRAs of renewable energy technologies in the road infrastructure

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Deliverable 2.1

Report of main renewable energy technologies (RETs) for the road infrastructure

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Review of conventional RETs suitable for NRAs

- Conventional RETs here considered for electricity generation:
  - Wind energy (large & small)
  - Solar PV energy
  - Small-scale hydro power
  - Micro-scale biomass power plants

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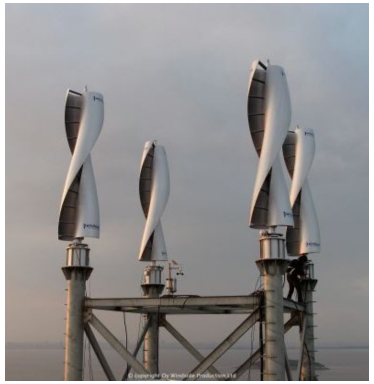
Review of conventional RETs suitable for NRAs

Wind energy

- A review of HAWTs and small VAWTs was carried out.
- Large wind (0.8 - 15 MW) & Small wind (up to 50 kW)
- Parameters involved in the review:
  - Elements
  - Size (and relation to performance)
  - Performance (power coefficient)
  - Location
  - Spacing (wake effect)
  - Distance to road, airports and comm systems
  - Logistics
  - Safety and security



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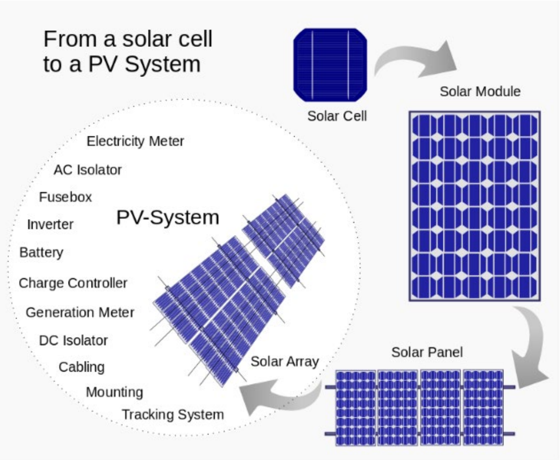
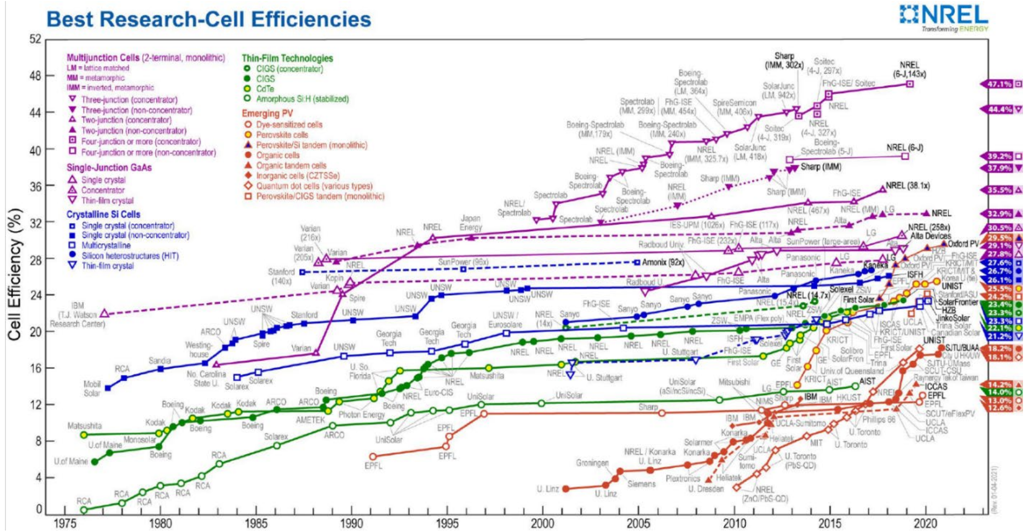
Review of conventional RETs suitable for NRAs

Solar PV energy

- Definition of electricity generation by the photovoltaic effect.
- Analysis of different existing cell technologies
- Cell → Module → Panel → Arrays → PV System
- Parameters involved in the review:
  - Elements of the PV system
  - Technologies: characteristics, performance and evolution
  - Typologies: isolated and grid-connected
  - Potential locations
  - Cleaning & Maintenance (effect on performance)





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Review of conventional RETs suitable for NRAs

Small Hydro

- Classification
- Main typologies
- Components
- Performance.

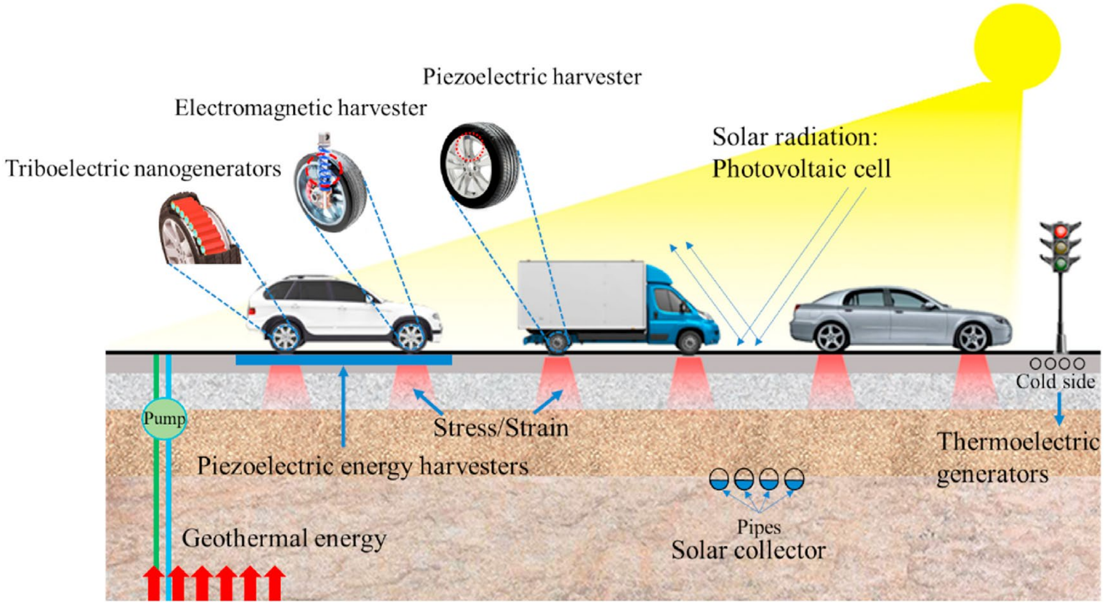
Micro scale biomass power plants

- Intro to biomass power plants and main components.
- Advances on micro-sized combined heat and power production units (< 15-50 kW power output).

Built-in [non-conventional] RETs suitable for NRAs - Energy harvesting -

- A good number of research institutions are doing research on less conventional energy harvesting in roads.
- Roads are subjected to solar and vehicle loads, thus generating low power output otherwise dissipated.
- Applications: street lamps, traffic lights, sensors for structural health monitoring, etc.

- Review of technology and current experiences
- Here reviewed:
  - Solar energy harvesting:
    - Solar PV in roads
    - Thermoelectricity generation
  - Kinetic energy harvesting:
    - Piezoelectric energy harvesting
    - Electromechanical generation



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Built-in [non-conventional] RETs suitable for NRAs - Energy harvesting -

Working principle: seebeck effect

TE Generators (TEG)

Power outputs of 0.05 – 0.5 W/m2

Energy generation of 5-25 kWh/day

Not economically competitive yet.

Fully embedded. Depends on ΔT?

Working principle: piezoelectricity

PE harvesters (PEH)

Power outputs of 0.009 – 9 W/m2

Energy generation of <1-180 kWh/day

Not economically competitive yet

Fully embedded. Durability?

Working principle: induction law

EM harvesters (EMH)

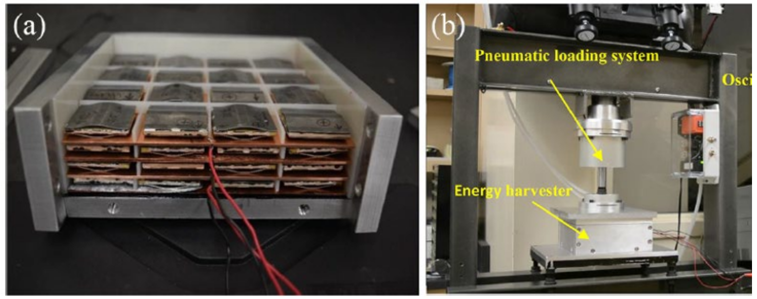
Power outputs of 0.003 – 3 W

Energy generation of ≈0.15 kWh/day

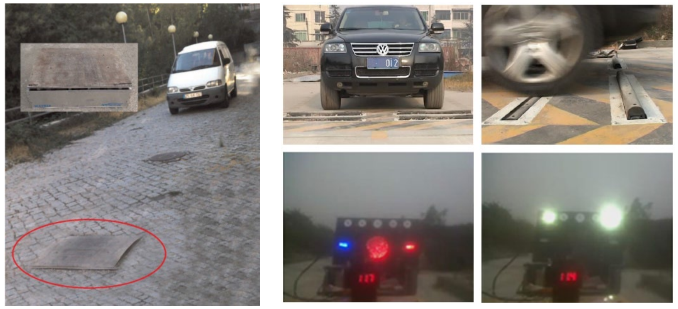
Not economically competitive yet.

Partially embedded. Few cases. Damage?

Thermoelectricity generation



Piezoelectric harvesting



Electromagnetic generation

Current experiences of RETs within the road asset worlwide

- Aim: search of potential topologies and locations for the implementation of RETs
- Parameters involved (not always found):
  - Technology
  - Power output
  - Energy supplied
  - Location
  - Topology
  - Maintenance events
  - Social importance
  - Budget
- Over 70 experiences found worldwide.
- Countries with more experiences so far (2020): NL, US, CH and DE (+ only few more).
- Important brands such as SolaRoad (NL) or Wattway (FR).

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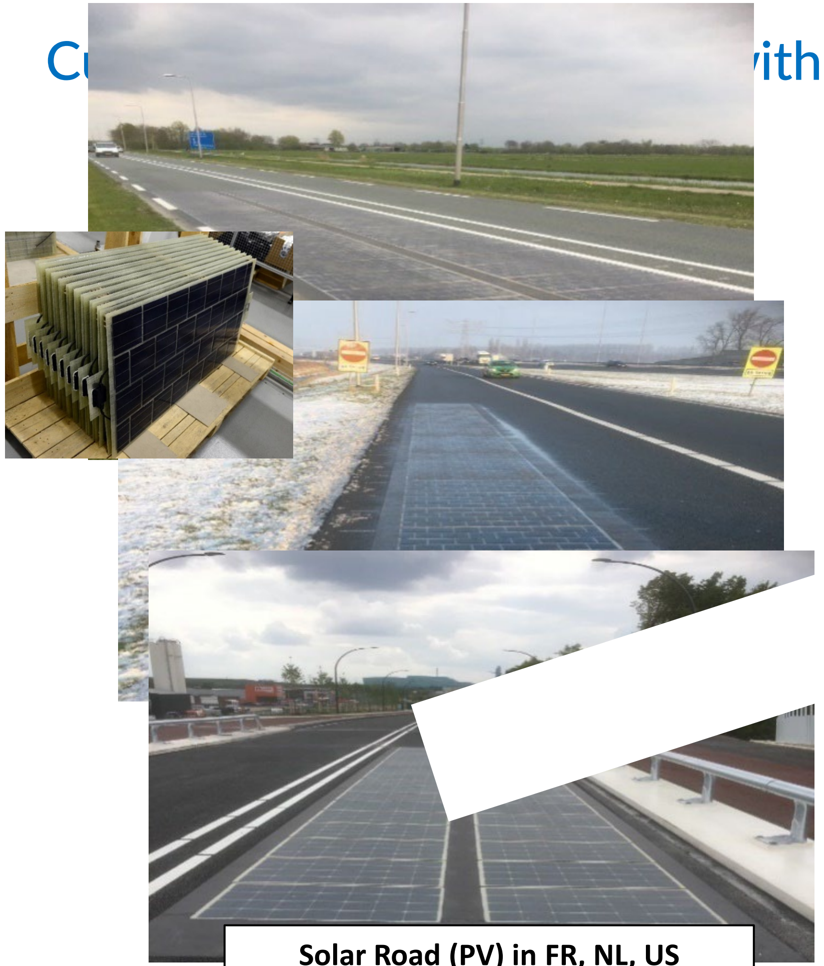
Current experiences of RETs within the road asset worlwide

- 4 main groups were made based on the technology and topology involved:
  - Solar PV panels integrated into the road pavement (a.k.a. solar roads).
  - Solar PV panels integrated into the noise barriers (a.k.a. PVNB).
  - Solar PV panels/wind turbines in big areas aside or out of the road.
  - Solar PV panels/microturbines in rooftops of buildings or infrastructures.

Selection of RE generation technologies and ES systems

Some examples…



Solar Road (PV) in FR, NL, US
Pilot projects under monitoring
Small sections (40-50 m2)
Grid-connected or off-grid

Bifacial PVNB along A50 road (NL)
Total budget of almost 5 M€
1.4 M€ EU Funding
203 MWh generated during year 1

Baldock Solar Station, Oregon DOT
Safety rest area with 7000 PV panels
1.75 MW & 1.97 GWh/year
Public-private partnership (PPP)

Selection of RE generation technologies and ES systems

ENROAD Survey: methodology

- The survey was designed and sent to several different NRAs stakeholders in the EU in order to:
    - Test their interest on the topic.
    - Collect information about their environmental targets, if any.
    - Collect their opinion on the criteria used for the selection of RETs, topology and locations.
    - Collect information about previous experiences on the topic.

- Simplest and minimum possible number of questions were generated in order to maximize participation.
- Survey sent to representatives of NRAs of following 28 European countries.
- More than 100 emails sent.
- At least one representative of 16 countries sent a full answer to the survey (60% success).

** Not necessarily official responses from the NRAs but mere contributions to this project by people involved to a certain extent in the management of the road infrastructure (i.e. managers, strategic advisors, heads of technology, etc.).*

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ENROAD Survey: some answers

- 75% of NRAs have internal targets to reduce energy use and/or GHG emissions, only 50% of them currently generate renewable electricity within their assets.
- Savings in electricity cost and social demand were the most preferred reasons for the investment in RETs by NRAs generating RE, but followed very closely by the reduction of GHG emissions and the fossil fuels.
- Economic and regulatory barriers are mainly preventing NRAs from investing on RE technologies.
- Small PV, small Wind and large PV are the RETs mostly considered by NRAs for implementation.
- Road and tunnel lighting and EV charging are the most preferred energy consumers for the RE generated.
- Avoiding traffic disruption, impact on road safety and distance to the road are the criteria most voted for the location of the RE technologies.
- Rest areas (80%), canopies (75%) and signals & panels (65%) were said to be the most convenient topologies for the RETs.

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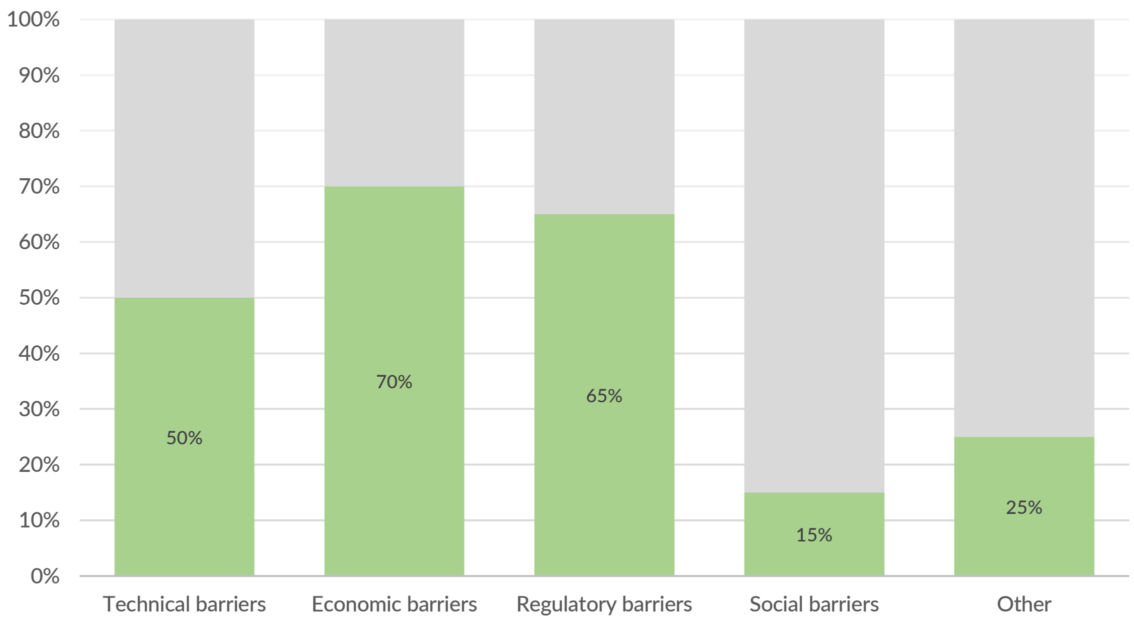

Cost of investment, long authorization and administrative procedures, no feed-in tariffs for public bodies or not being primary purpose for NRAs are some of the specific answers obtained.

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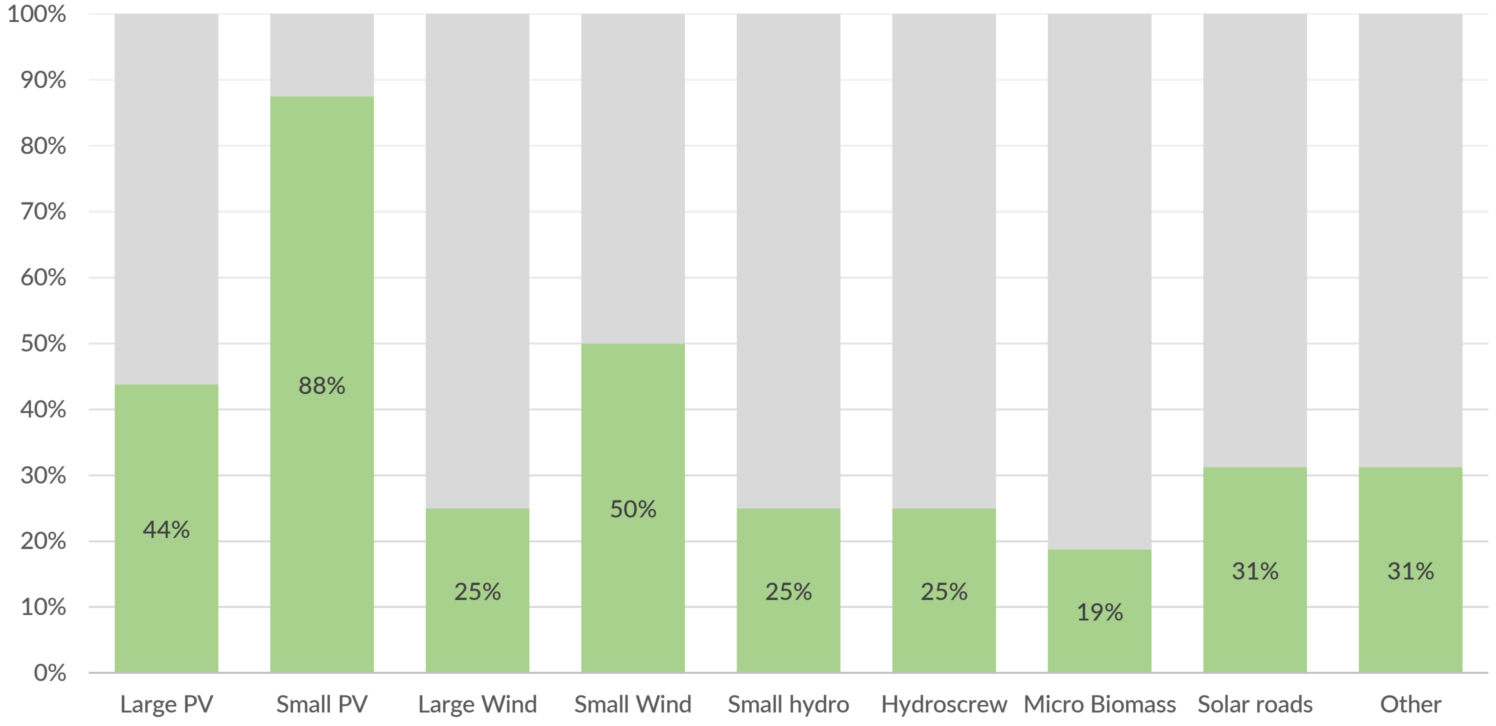

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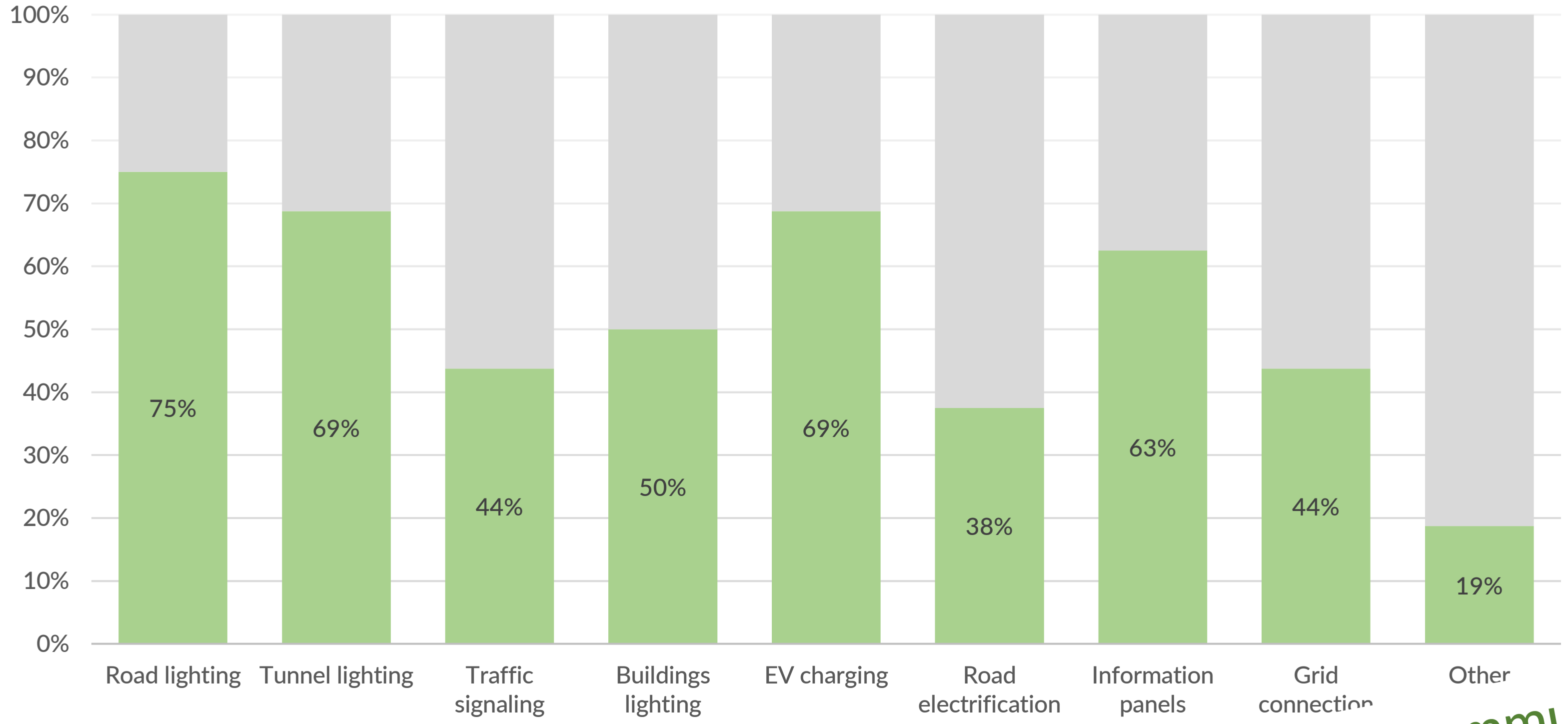

Other: Light tail transport, animal warning signs and communication in remote areas and support of heating (in buildings).

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Selection of RE generation technologies and ES systems

Initial screening & conclusions

- Based on TRL, current experiences and ENROAD survey.
- Technologies for the purpose of the ENROAD:
  - Large wind: mostly small to medium size.
  - Small wind except Vortex (Savonius: lower performance).
  - All PV except for Multi-junction and Organic technologies.
  - Silicon Monocrystalline are the most widely used.
  - Small hydro power plants using small hydro technologies.
  - Micro biomass CHP is a promising technology for large buildings.
  - TEGs, PEH and EMH: very low conversion efficiencies and lack of proper large-scale experimental tests.
  - Solar roads: high TRL, low efficiency and maintenance problems.

Technologies		TRL	MRL
Wind Turbines (Large and small)	Three-bladed	9	9
	Savonius	8	7
	Darrieus	8	7
	Venturi	7	2
	Small three-bladed	9	9
	Vortex	5	1
Photovoltaic (PV)	Silicon Monocrystalline	9	9
	Silicon Polycrystalline	9	9
	Silicon Amorphous	9	9
	Thin film technologies	8	6
	Multi-junction	5	2
	Organic	5	2
Mini Hydro	Pelton	9	9
	Francis	9	9
	Kaplan	9	9
	Ossberger	9	8
	Turgo	9	8
Micro-Scale Biomass	Micro-Scale CHP plants	8-9	5-6

Technology	TRL	MRL
Solar PV roads	8-9	2-3
Thermoelectric	3	1-2
Piezoelectric	4	1-2
Electromagnetic	3-4	1-2

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Initial screening & conclusions

- Spacing: a spacing btw tubines was defined by default based on the review of technologies (9D & 4D).
- Distance of turbines to the road:
    - Very few references
    - 100-150 m (ice fall)
    - 100-500 m (noise)
- Logistics is also to be considered, especially the access road: resistance to heavy loads, smooth slopes...
- Distance of turbines to airports/airfields:
    - Very few references
    - Turbulence affect especially to light aircrafts. Also an obstacle for them (less restrictive)
    - 2.5 km – 6.7 km for small to medium size turbines
- Distance to radar facilities: infill radar.

Initial screening & conclusions

- Solar PV is the most versatile technology for application along the road asset. Based on experiences and the ENROAD survey, rest areas (large PV), canopies, signals and panels (small PV) are preferred topologies.
- Air pollution and soiling of PV panels can greatly affect energy generation, but no specific references have been found on dirt/exhaust from vehicles. Regular clean up is thus essential.
- Accessibility to equipment is key for monitoring and maintenance, but adequate protection and locking of items should be considered to reduce the cost of vandalism.
- PVNBs seems to be suitable in terms of energy efficiency, maintenance and durability. However, the newest elements are only 2-3 years old so monitoring is required in order to validate their financial viability.

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Initial screening & conclusions

- For the purpose of the ENROAD tool:
  - Large wind (0.75, 2.0 and 3.3 MW)
  - Small wind (3-bladed and Darrieus)
  - Monocrystalline PV (330 and 530 W)
  - Small hydro: initially included (water storage) but then discarded
- Next steps:
  - Modelling –parametrization- by SINTEF Energi of the selected technologies.
  - Design of ENROAD GIS-based tool.

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THANK YOU!

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