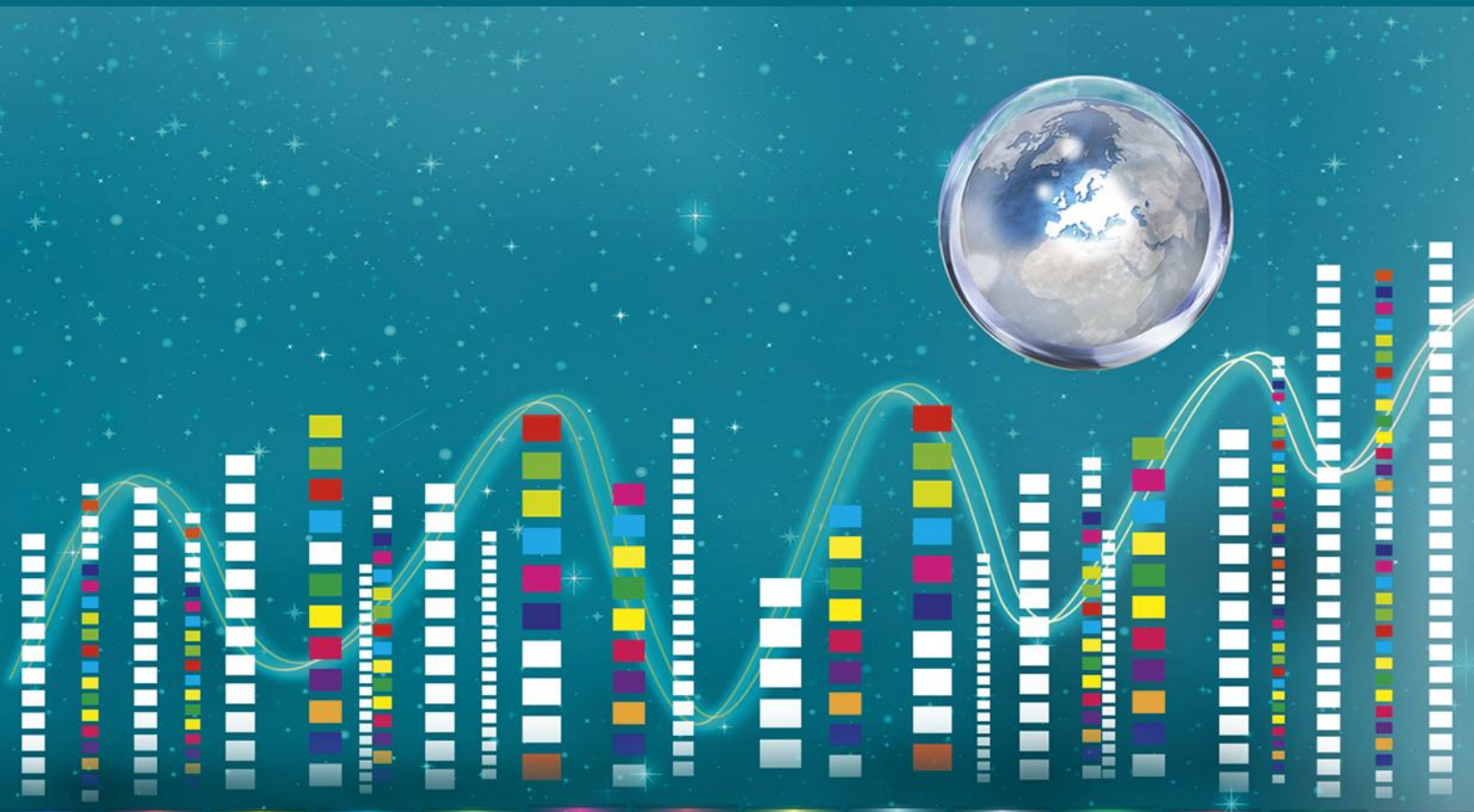
European Commission

Foresight

Cheap renewable energy

Targeted scenario N°3

Glimpses of the future from the BOHEMIA study



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Research and Innovation

EN

***Cheap Renewable Energy*- Targeted scenario N°3**

European Commission
Directorate-General for Research and Innovation
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EUROPEAN COMMISSION

Cheap Renewable Energy
Targeted scenario N°3

Glimpses of the future

from the BOHEMIA study

Directorate-General for Research and Innovation

2018

About BOHEMIA

BOHEMIA is a foresight study (contract N° Contract PP-03021-2015) designed specifically to support the preparation of the next framework programme.

The study put forward policy recommendations for the next framework programme, based on a foresight processes involving scenario development, a Delphi survey and an online consultation.

As part of its recommendations, the study identified 19 likely future scenarios with disruptive implications and associated priority directions for EU research and innovation.

The full range of the results of the study is available at https://ec.europa.eu/research/foresight

Targeted scenario N° 3

Cheap Renewable Energy

Summary

It is 2040. Renewable Energy is available at competitive prices. More than half the electricity used for transport, housing and industry comes from renewable sources. A pan-European smart grid coupled with local micro-grids, with adequate storage facilities, ensures reliability of electricity supply. Hydrogen and biofuels complement the system. The sector is expanding to novel cultivations, such as algae and bacteria.

UN Sustainable Development Goals (SDGs) most relevant to this scenario:

The scenario

By 2040, renewable energy sources are widely available, generating more than half of EU electricity. Solar power generation makes a huge difference in Europe's grid. Prices have collapsed, efficiency has increased and painted cells are common-place in new buildings. Wind and wave energy also contribute. The smart grid is underpinned by an extensive ICT layer that enables high interoperability of network operators and by devices, allowing for real-time interaction among all actors in the system. This pan-European smart grid is coupled with local micro-grids, which are built up through community-based projects and citizens' crowd-funding. Integration of storage facilities in the grid ensures reliability of supply. EU-wide utilities offer flexible tariffs in a highly competitive electricity market with full participation of consumers. Low and medium voltage electricity is sourced from medium and small-scale plants, down to micro-generation by prosumers. For high voltage distribution the grid relies on large offshore generation plants.

Solar water-splitting technology is widely used in the EU to store energy. The hydrogen thus produced is commercialised through a dedicated infrastructure, meeting the increasing demand and supporting the diffusion of hydrogen powered vehicles. These vehicles, equipped with a new generation of cheaper fuel cells, together with other electric vehicles and biodiesel heavy-duty vehicles provide for the needs of road transport. Electric vehicles provide also storage capacity to balance the electricity flow at the low voltage level.

Biomass is used in the residual thermo-energy production, as their carbon-cycle emissions are lower than fossil fuels. EU countries not only exploit almost all urban and agricultural waste for energy production, but also develop new and cleaner bioenergy sources. More than 5% of the production of bio-energy in the EU is based on algae and research is ongoing to make bacteria able to produce carbon-free hydrogen fuel.

For low power devices, all potential sources of energy – from body movement to sweat, tears, and even blood – are exploited. Companies developed power-generating systems for pavements, football fields and even school corridors using kinetic tiles that harness energy. Improved energy harvesting has extended battery life and even managed to do away with battery replacement in some cases. Autonomy from the grid increases. All mobile and remote electronic devices use technologies that are energy-self-sufficient and wireless.

Relevance for Europe

Climate change makes the decarbonisation of energy production imperative for the world as a whole. By leading in the efforts to decarbonize energy production and consumption, Europe will place many of its industries, from power plants based on combined heat and power (CHP) to network management software, at the forefront of global competition.

Contribution towards the UN Sustainable Development Goals (SDGs)

Combined with other determinants, RES can contribute massively to combat climate change and its impacts (SDG 13) and help ensure sustainable consumption and production patterns (SDG 12).

Renewable energy sources are necessary to achieve SDG 7, and ensure access to affordable, reliable, sustainable and modern energy for all, and its specific target to increase substantially the share of renewable energy in the global energy mix.

Implications for EU policy

Climate change related regulations and energy market regulation are key elements of a policy to support the use of renewable energy sources. A clear regulatory framework that would promote the integration of renewable energy sources to the energy grids while intensifying competition between suppliers. Structural interventions are also needed to fully integrate renewable energy sources. To maximise utility, it is worth to identify specific areas where the main grid can be substituted by micro-scale grids. Along with structural transformations and the dynamism of the EU energy market, consumers' behavioural change can drive the transition of the socio-economic system that would favour the transition to renewable energy sources.

Future Directions for EU R&I policy recommended by the public consultation

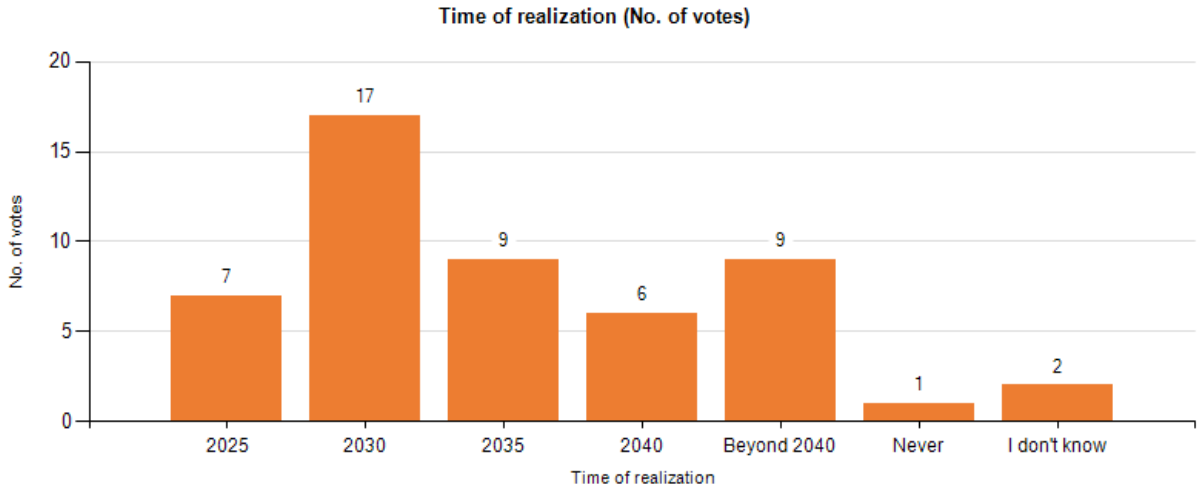
- **Methods, practices and solutions to promote energy saving and reduction of energy consumption**
- **Exploration of energy storage solutions, beyond batteries**
- **Energy efficiency measures, controlling the rebound effects, especially for buildings sector**
- **Developing optimal regulatory framework and incentives for long term systems change toward 100% renewables**
- **Smart grids deployment, including aspects such as infrastructure, demand response services and blockchains**
- **Research on artificial photosynthesis**
- **Incentive schemes to promote products and services with minimum environmental footprint**
- **Research and exploitation of energy harvesting**
- **Research on batteries**
- **Research on hydrogen fuel cells**

Annex: Relevant Data from the Delphi Survey

The Delphi survey of the BOHEMIA study asked experts about the time of realization of 143 statements about the future, and about the relevance of Research and Innovation for that realization, or about the relevance of the realization for Research and Innovation policy. The experts were asked to justify their judgements with arguments. The whole data set has been published and can be found at: https://ec.europa.eu/research/foresight

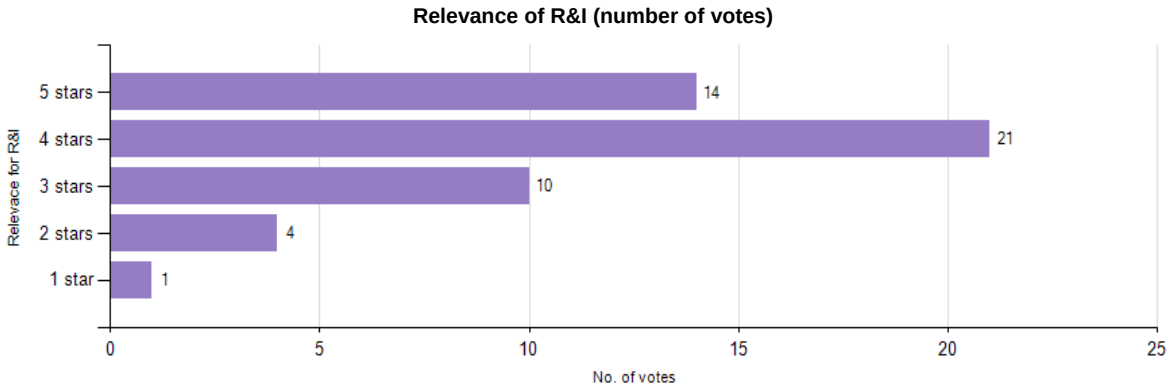
This annex includes the parts of the data set that are relevant to this scenario.

5 % or more of the production of food, medicine and bio-energy in the EU is based on algae



Number of respondents : 50

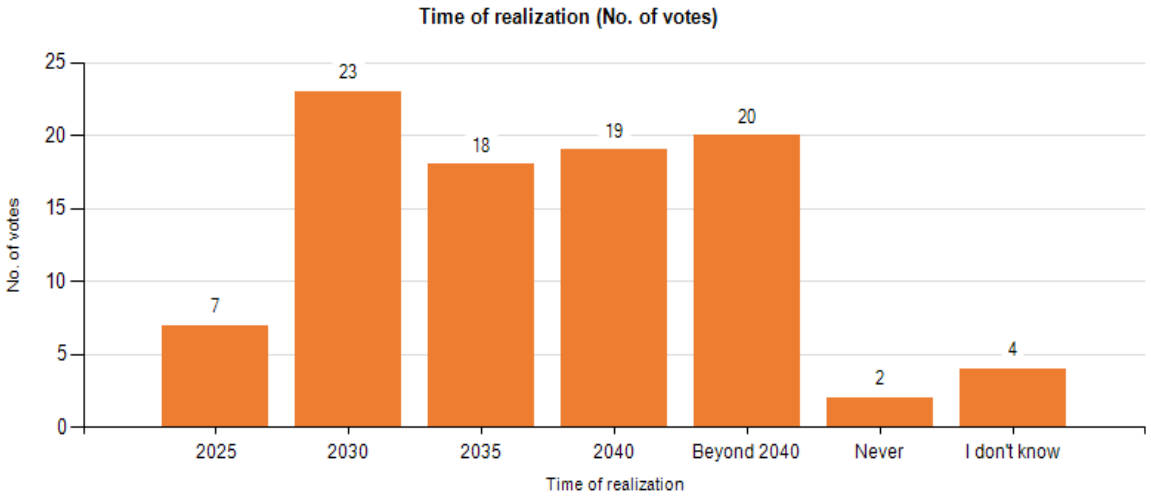
Arguments for time of realization	**No. of votes**
Industrial-scale demonstrations of sustainable algae cultures for biofuel production are available.	40
Algae research gives hope for renewable carbon-negative source of food and medicines.	29
Growing algae for food and biofuel contributes to the reduction of greenhouse emissions.	22
There are still simpler alternatives and options within the current land-based food system.	8



Average: 3.86 **Dispersion:** 0.96

Arguments regarding the relevance of R&I	**No. of votes**
There is need for further research on the manufacture of bio-compounds from microalgae with applications in food production.	44
New research may exploit the ability of algae to produce lipids using energy from photosynthesis.	31
research on algal growth conditions and on which variety to use for which purpose is still required	15
Further research on bio-refinery of algae and consumer acceptance of algal products is required.	4

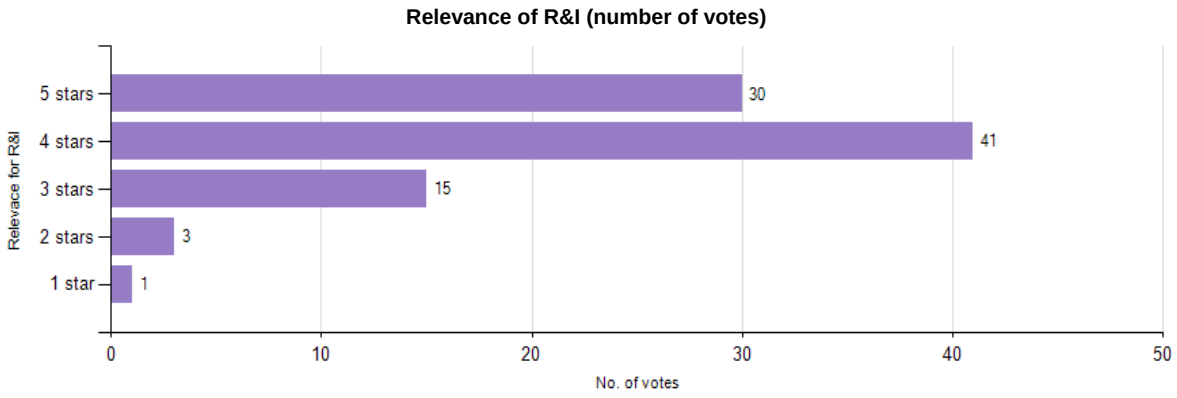
The EU produces 50% of its electricity for transport, housing and industry from renewable sources



Number of respondents : 92

Arguments for time of realization	**No. of votes**
A strong learning curve of energy storage options and smart energy solutions helps to deal with the volatility of the intermittent generation of renewables.	78
The price of solar per Watt has almost halved between 2010-2015, and continues to fall.	41
The need for energy security is pushing Europe in this direction.	23
Renewables have their own environmental problems.	23
Cost reduction of renewables makes them competitive with other sources, with the additional advantage of being carbon-free.	19
There is a continuous diversification of renewable energy production, which will probably result in the large-scale adoption of certain technologies.	15
A strong push towards electric vehicles and new technology such as self-driving cars will cause a shift to cleaner transportation.	14
Consumers prefer renewables; the prices of storage and local generation will fall lower than grid power.	12
Role of nuclear energy is significant to reach low-carbon targets.	11
Germany already reached 40% energy production from renewables in 2016, more than doubling the percentage from 2010.	9
Flexibilisation of demand (demand response).	8
Renewable energy is growing fast and will continue to do so. But the timing for reaching 50% will be pushed back by the increase of electric vehicles, the rate of which is an unknown.	6
Beside all technical solutions, a mandatory requirement was a broad user acceptance of all societal groups and stakeholders – achieved with tailored concepts of information and motivation.	5

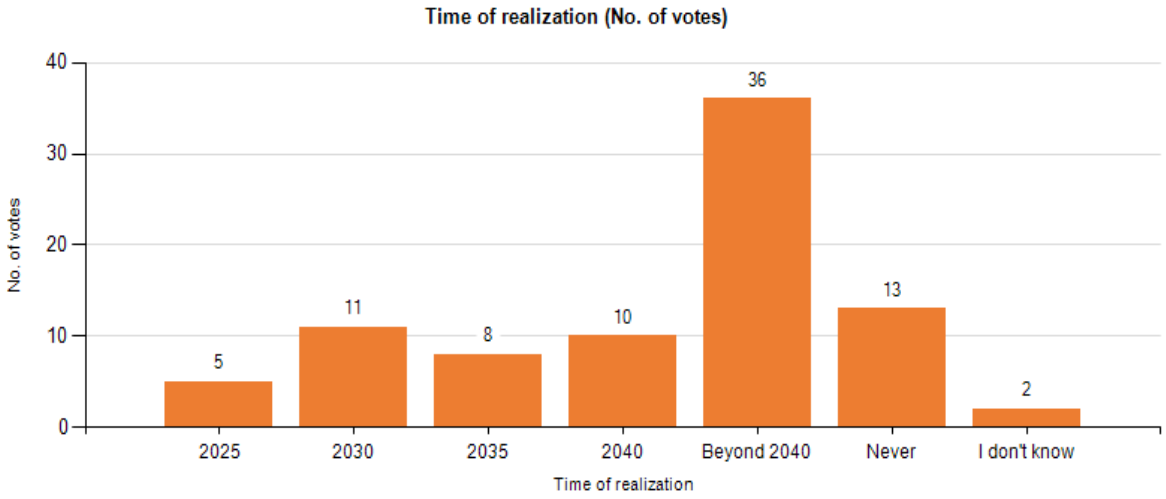
In Bavaria, there is a community (Wildpoldsried) that already in 2016 produces 5 times the energy it needs for itself. Why not learn from this and similar communities?	5
This trivialises the issues involved. There is more to energy than a few windmills. Integrated energy systems - e.g., zinc or aluminium for air cells - will take massive effort.	4
Convergence of renewable energy technologies will deliver higher value to the customer (heating, cooling, electricity).	3
Microgrids will go much of the way, but need to interlink with other microgrids and the smart grid, and need ICT technologies to enable such inter-operability, self-monitoring and context awareness.	3
Access to the future electrical energy supply needs affordable, available and sustainable generation and storage opportunities.	3
The definition of renewable must be updated, because it is not independent from non-renewable, and therefore 50% is actually, even beyond 2040, too high a target.	3
It is crucial to efficiently use energy through friction and wear reduction, with decreasing of transport through remote work and with change in human's high-cost energy habits.	2
Beside (renewable) energy (kWh) production, sufficient generation of power (kW) must be guaranteed. Only the combination will lead to the desired success.	2
All energy generators need a level playing field within a carbon-free future electricity market.	2
This is our forecast from www.TechCastGlobal.com	2
PRIMES scenario in the context of Clean Energy for All Europeans points to such 50% penetration in electricity to achieve the 27% renewables target.	2
EU public is not ready for a flexible renewable energy consumption as needs to be key factor to ensure 100% successful implementation	2
The use and development of microgrids enables communities with local generation and management of their own energy needs, eliminating transmission losses etc.	1
The future challenge will be to secure the CO2-free electrical energy supply.	1
Strong efforts in energy efficiency and energy saving will allow to reduce the overall electricity consumption in all sectors.	1



Average: 4.07 **Dispersion:** 0.70

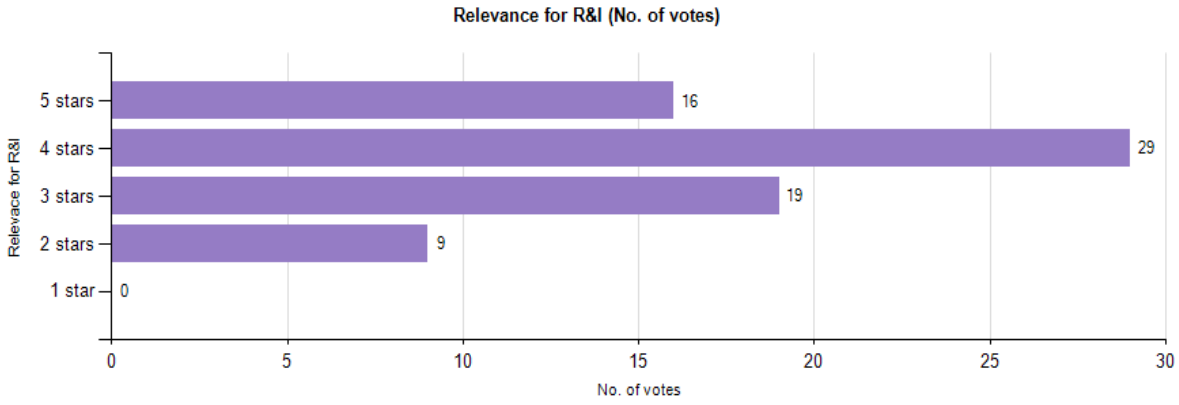
Arguments regarding the relevance of R&I	**No. of votes**
The energy mix at national level remains dependent on the political will.	61
R&I on energy storage is key.	59
Beside the technical learning curve, we need a social learning curve. A community can take care of its own needs. R&I in the social context have to be accelerated and improved.	36
The need for a technology learning curve to reduce costs at the level of grid parity implies still huge investments in R&I, particular to develop innovative technologies like ocean energy, etc.	27
Human behaviour has to be subject to research in order to 're-organise' our consumption needs.	12
The development of thin-film solar cells could transform any surface into energy collection system.	11
A sustainable energy production method still needs to be found.	10
Increasing penetration of electric passenger cars market will drive the need for more power generation, more widely distribute electrical storage particularly for home use driving R&D + innovation system wide	8
Reducing the energy demand should be the first priority.	8
Energy storage and flexibility will be the future key issues - R&D and effective use of existing facilities (e.g. storage- and pumped storage hydro power)	6
We need solid & sustainable business models with benefits to all stakeholders and good M2M (machine to machine) & HMI (human machine interfaces) for this to happen	4
Research on how to convince people and enterprises to participate are needed for a successful implementation;	4
A critical review of energy production and consumption pattern throughout Europe is required to develop the system perspective	4
For this to work, we need to build an entire new energy system on new social & economic foundations.	3
To go further, beyond 50%, will require R&D but this share is already reached by some countries, region or territories	3
Breakthrough development on batteries is essential for breakthrough od renewables.	2

80% of all building surfaces in the EU that are exposed to sunlight are used for power generation



Number of respondents : 83

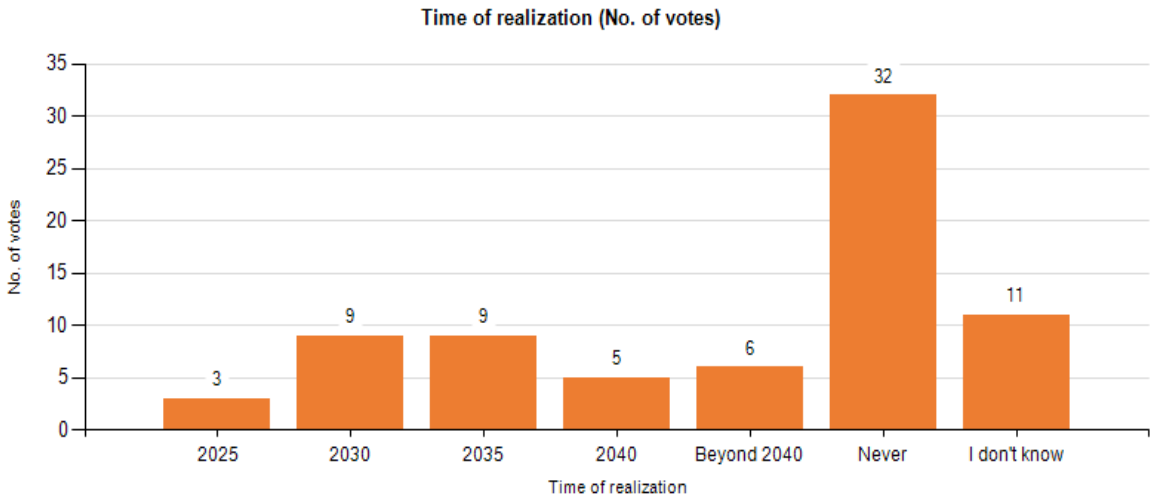
Arguments for time of realization	**No. of votes**
Buildings' refurbishment and renovation cycles offer the windows of opportunity to install solar power generation, but these are long-term solutions.	54
Individual owners and cultural conservationists will resist solar installations on some structures (ex. personal homes, and historical buildings).	38
A strong policy on energy renovation of buildings is needed to achieve an ambitious solar target.	35
PV is probably not the most economically (and environmentally) efficient solution (especially in the north of the EU), building-refurbishment is a current, efficient solution.	18
Retrofitting existing buildings may be problematic, and undesirable for certain types of buildings (heritage).	16
Decreasing costs and easy deployment of energy storage will reduce the value of generating power from existing buildings, largely limiting this option to new construction.	12
Thinking about the potential of artificial photosynthesis and its generation of chemical kinds of power (e.g. using north faces of buildings) will be interesting. It does not always need to be PV.	9
PV does not have to be the only option available. Other static technologies, such as thermoelectrics, could contribute to meeting the target.	7
In 2014, Michigan State University researchers developed a completely transparent solar cell that could become a perfect window replacement.	5
Much more has to be done with architects and owners to integrate the PV on new buildings and retrofitting existing building as a first option.	4
80% only realistic with strong legal or commercial incentive.	3
PV does not have to be the only option available. Other static technologies, such as thermoelectrics, could contribute to meeting the target. (4) (I cannot select this option)	3



Average: 3.71 **Dispersion:** 0.91

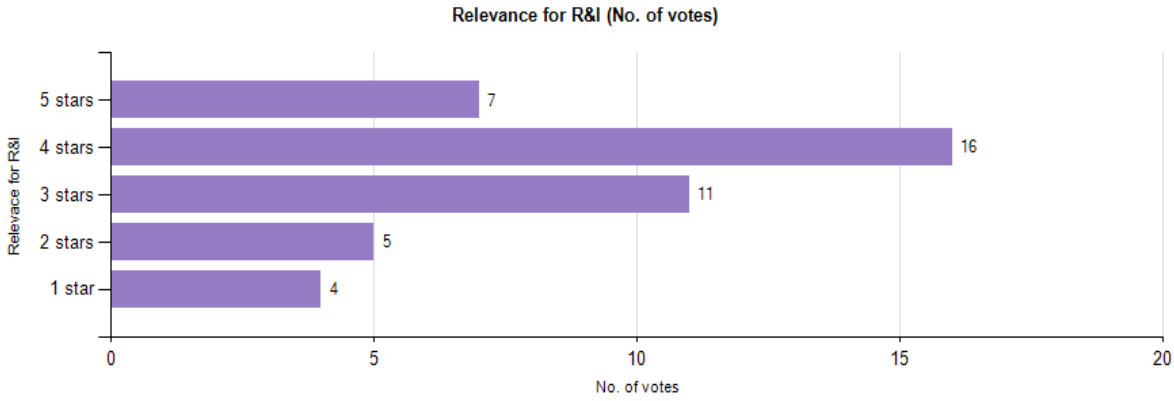
Arguments regarding the relevance of R&I	**No. of votes**
Research should look into making building-applicable solar technology as unobtrusive as possible - while still maintaining acceptable cost.	46
Social acceptance (and a change of mind of architects/builders) of these technologies will be as essential as technological advances...	37
If the cost and functionality of a solar roof is comparable to a traditional roof the solar roof will be chosen, particularly if there are government incentives. R&D to drive down costs is key.	21
There's a lot of promise not so much in using building surfaces, but in road / street surfaces, which, however, raise additional concerns about long-term reliability and maintainability - and these need systematic exploration.	10
Not a technical problem, more of a social and economic one. Besides, one wall of 4 is always pointing north, and one more is facing away from the sun at any given moment.	6

Solar thermal power plant electricity generation is available in every EU country



Number of respondents : 71

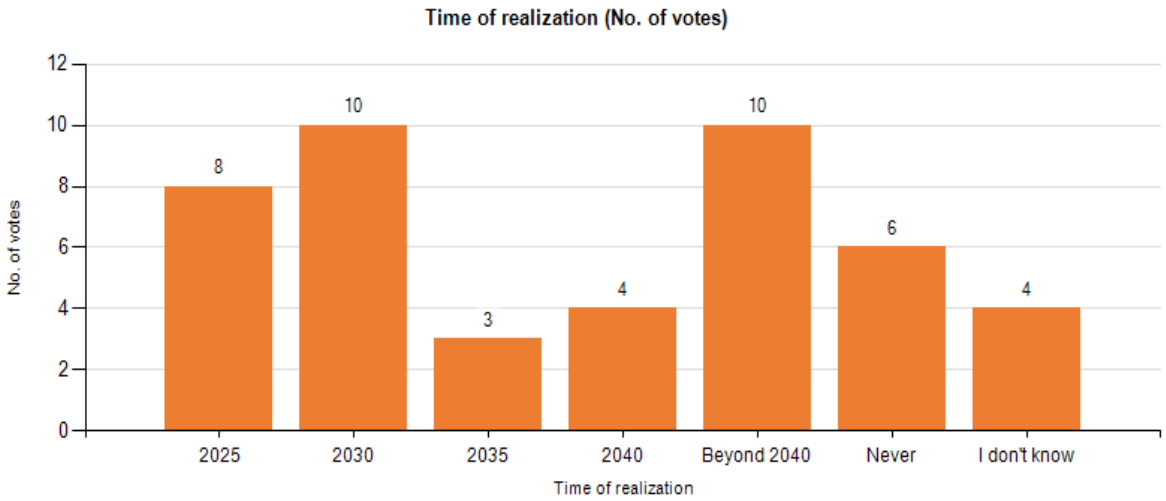
Arguments for time of realization	**No. of votes**
Nordic countries are not solar-rich enough for this technology.	41
Solar thermal plants only work for solar-rich regions where they can deliver base load energy and thus overcome their relative higher costs compared to solar PV.	35
"Available" is an easy target or goal.	15
According to ESTIF (European Solar Thermal Industry Federation) the market size for solar thermal energy has fallen in virtually every country in the EU in 2016, continuing a trend already manifest in past years.	13
The competition with PV remains difficult, despite the advantage of dispatchability.	8
Solar thermal power plants imply some form of concentration through mirrors, which uses only the direct and not the diffused radiation. There are hardly any suitable areas in Europe.	8
In 2015, only 4 EU countries had operational plants, and no other country in addition to these had plants under construction (Greenpeace 2016 report).	7
No specific efficiency targets and/or power requirements make this question useless in terms of discussion.	5
PV together with heat pumps is already more competitive for heating and cooling compared with solar thermal.	4
Why should solar thermal plants be in every EU country?	2
Solar thermal plants only work during daylight even in solar-rich regions.	1



Average: 3.40 **Dispersion:** 1.32

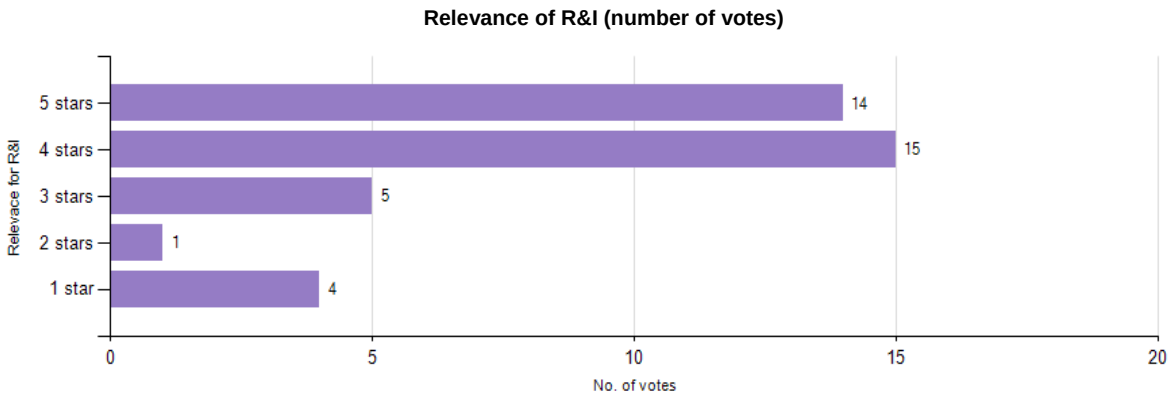
Arguments regarding the relevance of R&I	**No. of votes**
Research is needed to bring down the costs of solar energy.	32
Evaluate the impact of current technologies on wildlife and develop ways to mitigate it.	12
This could be done now.	9
Some current solar thermal plant technologies need a lot of water - an economic issue in some locations, which may however be tackled by innovative technologies.	5
Research for solutions with PV in combination with heat pumps are more relevant	5
No specific efficiency targets and/or power requirements make this question useless in terms of discussion	4

For the first time, bacteria are able to produce carbon-free hydrogen fuel



Number of respondents : 44

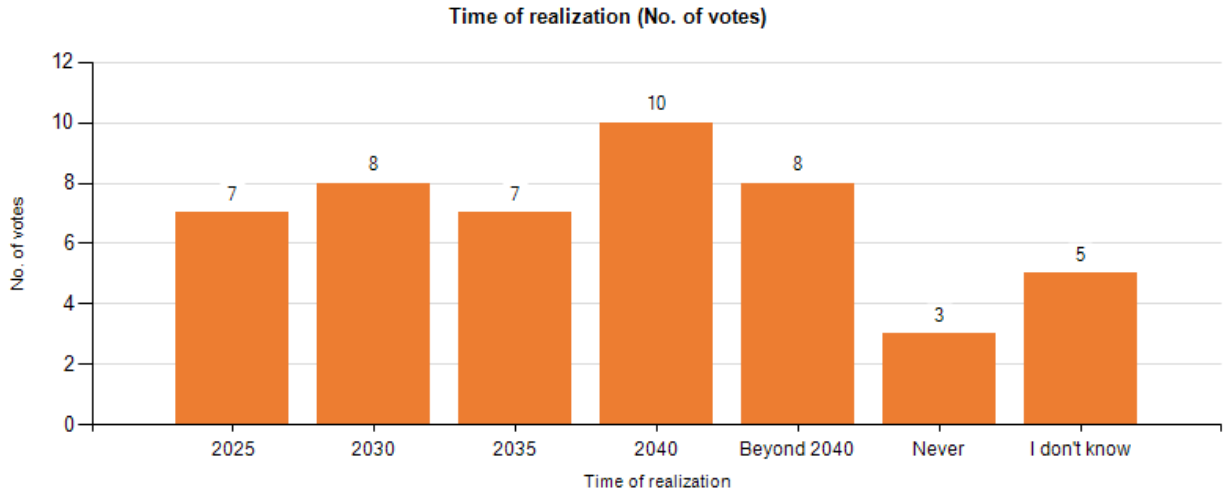
Arguments for time of realization	**No. of votes**
A lot of time is needed to produce the amount of bacteria necessary for significant effects on carbon-saving.	21
This is likely to happen, but conversion efficiency will lag way behind other methods (e.g. PV+electrolysis).	12
Researchers have engineered the E.coli bacteria to generate renewable propane.	12
Scaling up "synthetic biology" will make this available much sooner than we expect today (see: The Economist, 2017-05-06 "primordial gloop").	9
In a factory or in a test tube?	7
Silly nonsense. If you want hydrogen, make it in a desert somewhere. Then go to paraffin via syngas ex salt-water irrigated biomass. Better, skip hydrogen and go to reduced metals.	5
High likelihood, but multiple competing factors retard possible deployment. Options such as Indirectly-Heated Pyrolytic Gasification for production of H2 from local biomass could offer low-cost entry.	5
The topic is obsolete: Already biomass which converts CO2 into hydrocarbons is CO2 neutral. No need for H2 producing bacteria, which in turn create the need to set up H2 infrastructure.	3



Average: 3.87 **Dispersion:** 1.51

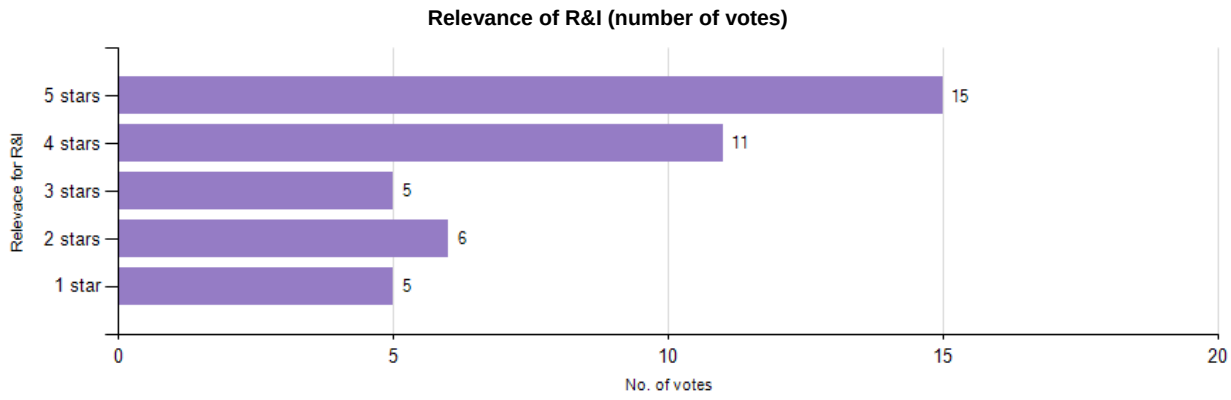
Arguments regarding the relevance of R&I	**No. of votes**
The efficiency of the process needs further improvement.	34
The ecological impacts need further research.	25
H2 economy requires wide deployment and a robust supplier base. Distributed low cost generation of H2 could accelerate the use and offer a market entry strategy.	6
Many other energy rich molecules can be synthesized by microbes. Electron storage in chemical bonds is favourable. But rather not H2 by microbes.	3

Energy harnessed from the human body is used in applications such as heart pacemakers, organ or brain implants



Number of respondents : 44

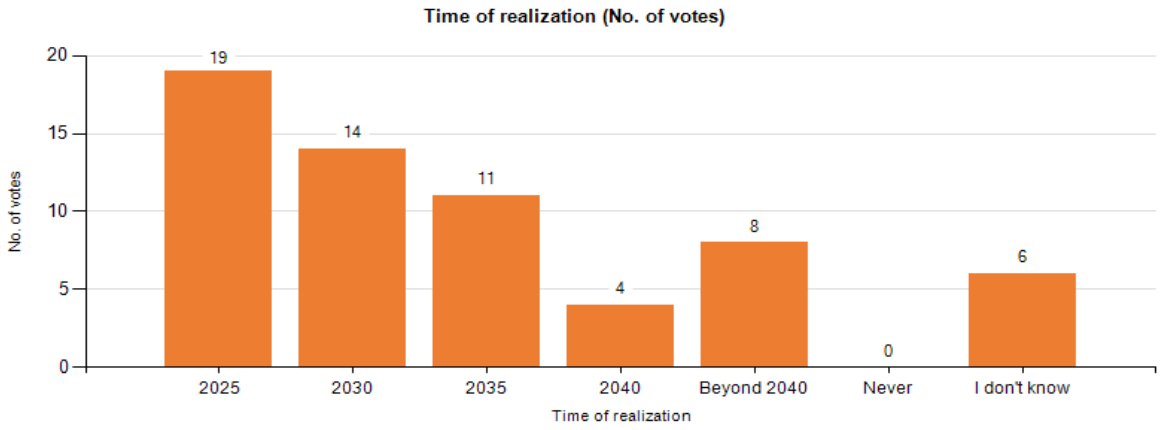
Arguments regarding the time of realization	**No. of votes**
Many potential sources of energy - from body movement to sweat, tears, and even blood - are being explored concurrently, increasing the likelihood of success in at least some of these cases.	28
Companies developed power-generating systems for pavements, football fields and even school corridors using kinetic tiles that harness energy.	12
Science fiction	10
This is not a reasonable solution for the Energy challenges in the EU, it could never be a significant contribution to the energy system compared to energy efficiency and renewables.	8
Bio-mechanical sensors are a hot topic (cfr. 'robotic hand') and already use small electrical signals produced by nerve endings. Next step to small energy production will be possible in near future.	5
Energy harvesting will extend battery life & sometimes eliminate battery replacement, but the power of IoT devices needs to reduce, and harvesting & storage technologies need to improve (HW, SW, system models).	5
Australian and Chinese researchers have recently produced the first 'smart fabric' capable of turning thermal energy into electricity.	4
Life extension made possible by various implants becomes feasible with sources of energy internal to the body that are not at risk of external damage. Cost assurance of safety will pace deployment.	2
A recent Swiss prototype of a skin-like filter uses solar energy to power a pacemaker.	2
People need to understand better the ambient energies available in most use cases and design around this power budget for hardware and software.	2
More energy from humans is available in used water and waste, if you really want to adress this issue. Orders of magnitude are important to keep in mind to really evaluate the potential of the human body.	1
There is already a prototype of a mechanically powered pacemaker. Think self-winding wristwatches...	1



Average: 3.60 **Dispersion:** 1.92

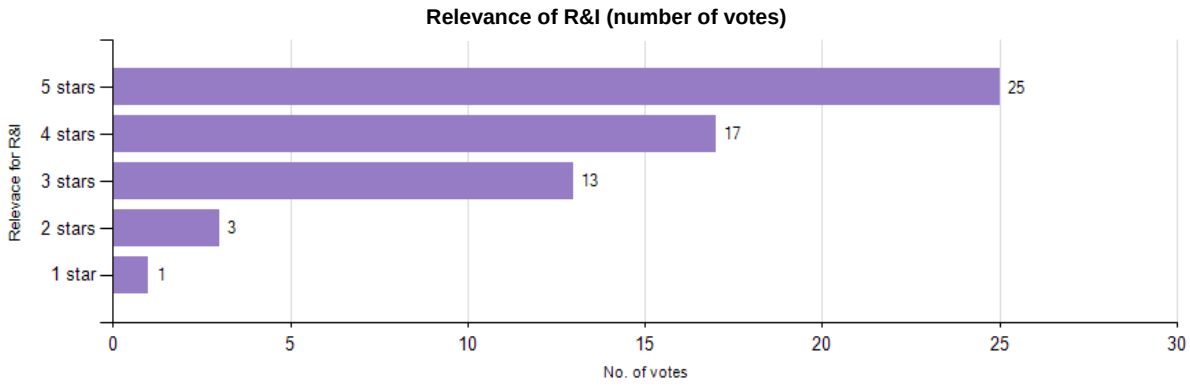
Arguments regarding the relevance of R&I	**No. of votes**
Research has to overcome a substantial efficiency barrier in using human body energy to power implants or wearable devices.	27
A breakthrough is needed in the field of very thin and flexible batteries for the technology to spread widely.	18
Sufficient energy is generated by bodily systems to power implants. Tapping that energy is a major research challenge.	6
Many of the systems which could be realized are based on materials properties, so material improvements are needed to achieve these targets	6
Better power management ICs based on real life ambient energies is needed	5
Lower power sensors and energy harvesting centric software to minimize IoT device power is critical - models to simulate application behavior is also critical	2
Energy saving, energy efficiency and renewables combined to a less consuming life style should be the ambitious goals to reduce our energy bill.	1
Less administration for prototyping can boost research and make the introduction in real practice easy to overwin.	1
Energetic self-sustainability e.g. for pacemakers is a very nice property for patients' well-being, but will not have significant impact to EU energy policy's goals.	1

Paintable solar energy cells, enabled by nanomaterials, are used for the first time on the roof of a large building (more than 100m2) in the EU to harvest electricity



Number of respondents : 59

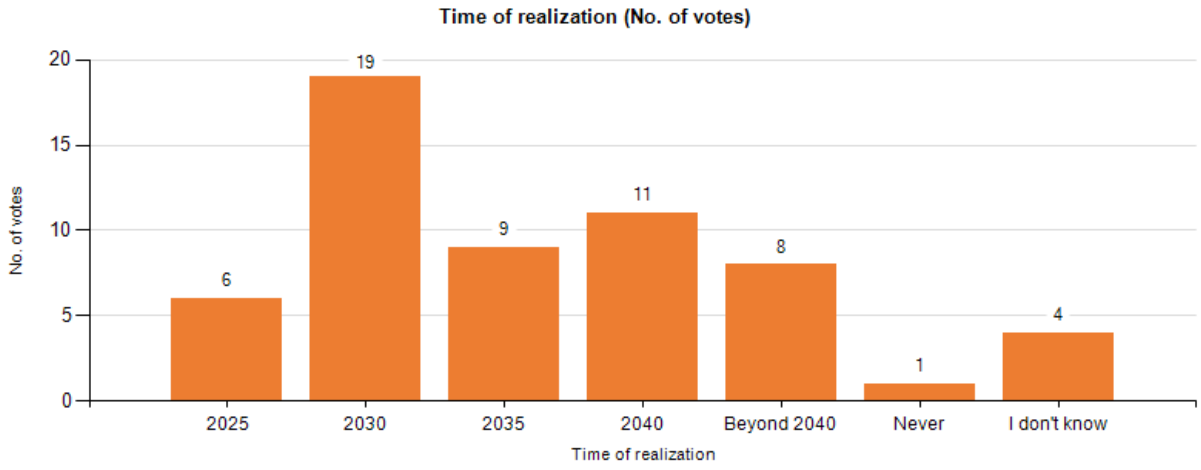
Arguments regarding the time of realization	**No. of votes**
The production, installation & maintenance costs for photovoltaic materials such as silicon are still high, so research groups are working on solar paint with increasingly better results.	39
The statement looks only for a demonstration project - after several years of research on the technology already it should be possible to demonstrate it on a roof quite fast.	23
Paint is relatively cheap, but how durable is it?	10
Painting implies a gross process even if nanomaterials are involved. 3D printing is an ultra precise process that can be viewed as a form of painting. Robotic 3D printing of photovoltaic surfaces.	8
To use non-toxic nanomaterials is difficult, but the first experiments with non-toxic salts were successful.	7
This is an oversimplified statement. Besides the "paint" (absorber), PV will always need cables, electrodes and wiring. These systems would need simplification and significant cost-down, too.	6



Average: 4.05 **Dispersion:** 1.00

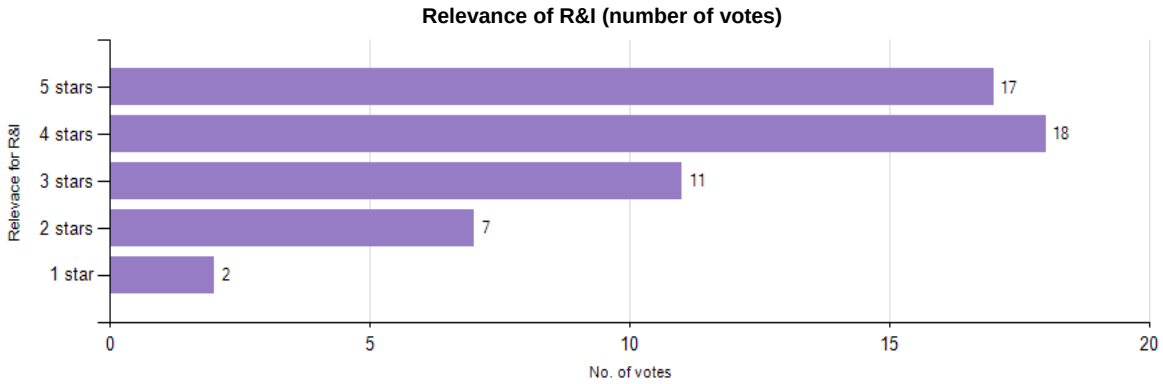
Arguments regarding the relevance of R&I	**No. of votes**
The challenge is to reach an efficiency level equal to or greater than silicon-based solar cells.	41
To be able to paint them on a large scale is a scientific challenge.	25
Clarification of toxicity is a research challenge that will also bring knowledge to other fields.	17
Maybe, this technology should not be used for roofs but for walls. 'conventional' silicon PV on roofs is fine.	9
3D printing of photovoltaic surfaces may be able to achieve higher levels of efficiency. The challenge is to lower the cost of 3D printing devices for this application.	5
We need further R&D to develop the triangle of 1) high efficiency and lifetime, 2) low cost (in module and system) and 3) social acceptance (non toxic, aesthetic for use in walls).	4
We will need to make a choice between cheap but inefficient and expensive but efficient.	3
Long-time durability of nanomaterials will be a key issue, in particular when exposed to light and heat	3

Solar water-splitting technology is used in the industrial and commercial sectors across the EU to store the energy from the sun



Number of respondents : 56

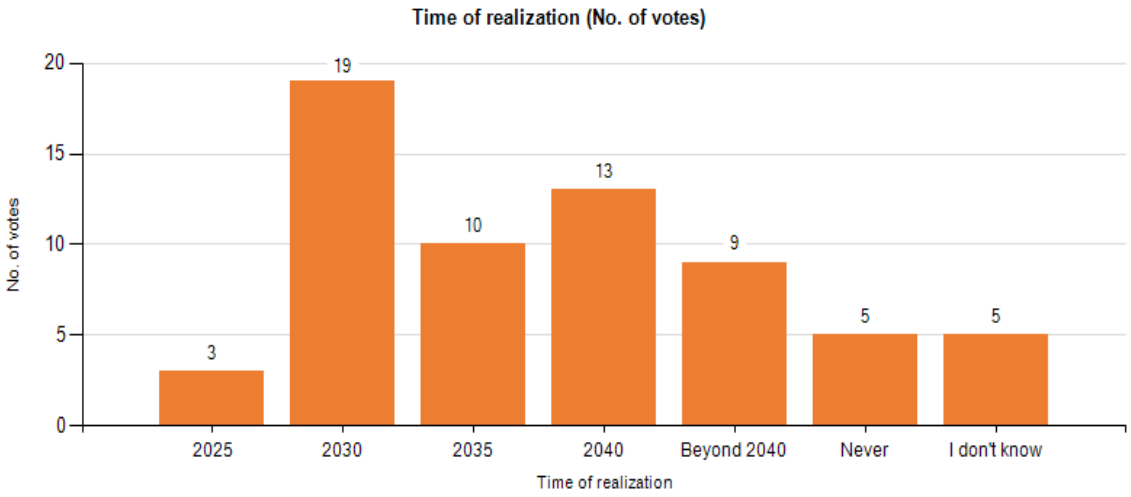
Arguments regarding the time of realization	**No. of votes**
Cheap water splitting devices that operate for a long time are still elusive, but researchers are working to develop them.	32
The demand for hydrogen is increasing fast.	24
More than 300 water-splitting cycles are described in the literature, which makes it likely that some of them will prove effective.	18
PV + electrolysis seem to be the winners currently, so this is part of the overall scientific challenge of PV efficiency/price.	14
The challenge is not the splitting but in the storage of H2 from small scale decentralized systems. Large scale H2 competes with electric and costs many billions. Decentralized H2 production needed.	13
Systemic problem, not a technical one.	5
You don't do this in the EU. You do it in N Africa. You make the H2 into something useful like a paraffin to move it. H2 itself is a dreadful fuel but a good reagent.	4



Average: 3.75 **Dispersion:** 1.25

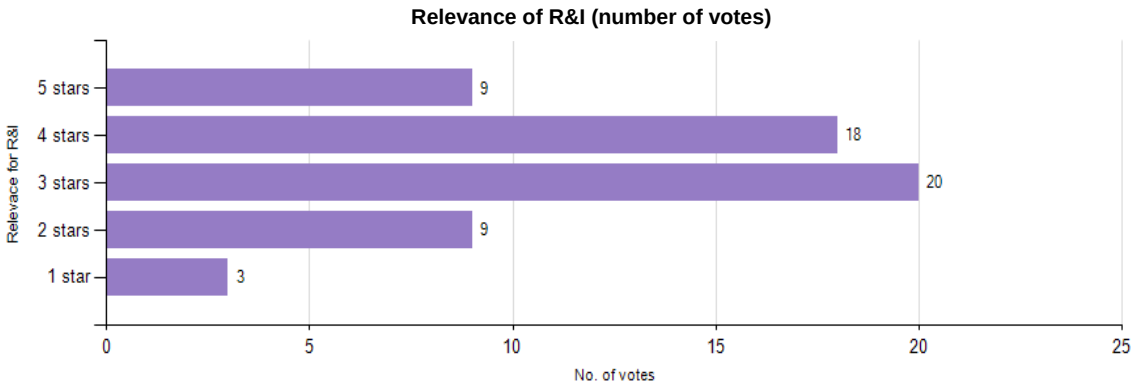
Arguments regarding the relevance of R&I	**No. of votes**
Need for developing methods to boost the longevity of high-efficiency photocathodes in photo electrochemical water-splitting devices.	32
There is a need for R&D on decentralized H2 production, storage and use.	29
There are more than 300 water-splitting cycles described in the literature - the most effective and useful ones must still be identified. Research on them is highly needed.	18
Systemic problem, not a technical one.	3
Not from "photosynthesis". Solar cells => electrolysis.	3

A hydrogen infrastructure in Europe has been built up and is in use



Number of respondents : 63

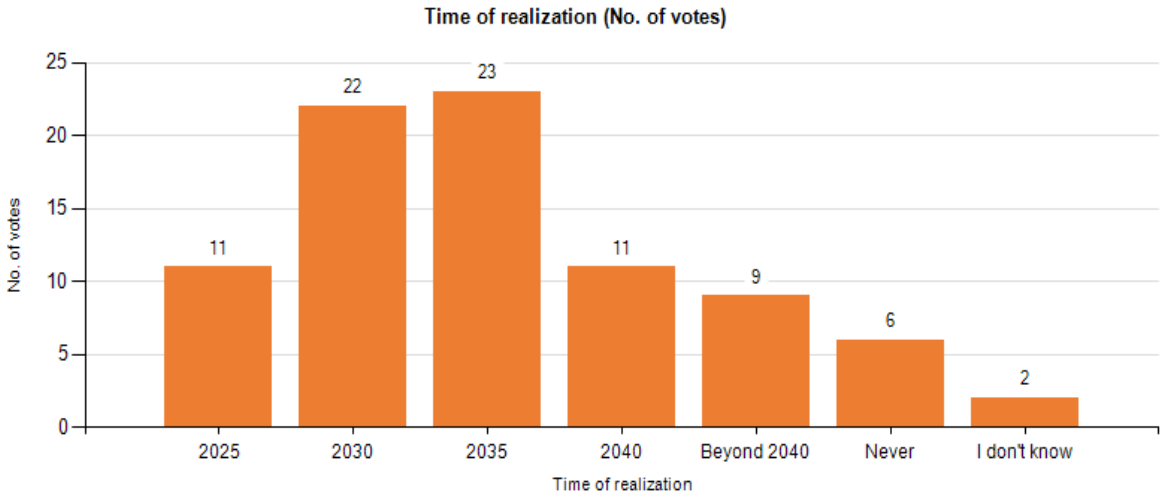
Arguments regarding the time of realization	**No. of votes**
The hydrogen infrastructure is under test in 10 countries.	25
There will be strong support from the car-maker industry.	24
Hydrogen (H2) and Methane (CH4) infrastructures will complement each other.	24
Electrically-chargeable vehicles represent a serious alternative to hydrogen. If electricity charging infrastructure develops well, hydrogen investments could be stranded.	17
The major investment required both in the infrastructure and in the automotive fuel cells and other devices will be difficult to justify in the face of rapid penetration of electrics in transportation.	10
There will be strong opposition from gas companies.	9
Public controversies about the aim and use of these infrastructures are likely to increase given the current paucity of public information.	6
Decentralized, small scale H2 production particularly from local biomass, storage and use, is a promising option for which infrastructure does not exist.	6
We will not be able to afford several new energy systems in parallel. With current political trends, electricity will be entrenched by 2030 and hydrogen will remain a niche or a curiosity.	5
This is a misconception. Hydrogen does not need "infrastructure", and the methane grid will not cope with molecular hydrogen.	4
In 2016, the European Union Horizon 2020 programme financed 20 extra hydrogen-refuelling stations in Europe.	4



Average: 3.36 **Dispersion:** 1.12

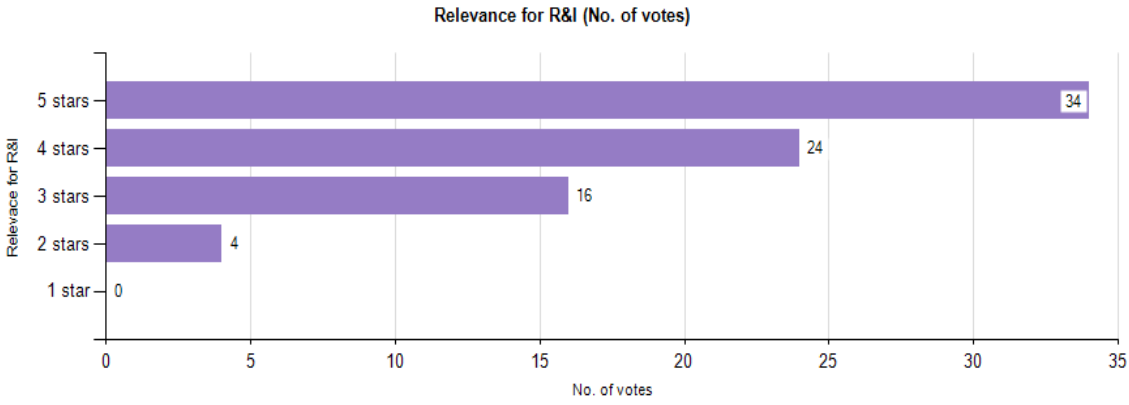
Arguments regarding the relevance of R&I	**No. of votes**
This is rather about the political will to adopt relevant public policies.	36
New technology is needed to increase the output of hydrogen production, reduce its cost, as well as reduce greenhouse gases.	34
Rather than technology maturity it is a matter of market choice and investment rationale.	13
Distributed, low cost small scale H2 production from local biomass and storage offers market entry for communities choosing the H2 path contributing to local jobs.	9
Why are none of these questions about actual, real world energy? This is all high school fantasy stuff. What about hydraulic fracturing? Russian dependency?	3
While fuel cells can be competitive if they are produced in numbers comparable to IC engines deployment, this demands the existence of an infrastructure that will cost more than that necessary for electrics.	2
The main question to be solved is safe large-volume H2 storage.	2
To produce H2 from biogas or other Biofuel materials is a nonsense. The CO2 emissions are not avoided.	2

All mobile and remote electronic devices use technologies that are energy-self-sufficient and completely wireless



Number of respondents : 84

Arguments regarding the time of realization	**No. of votes**
The number of compact, energy-self-sufficient, remote terminal units is increasing.	67
A large spectrum of energy-harnessing solutions from different sources are emerging.	59
Full replacement of existing technologies in this domain (all devices, 100%) will only happen if they are ruled out by regulatory measures.	31
Wireless charging is already on the market	20
Intelligence in combining all available energies in nature will accelerate the progress.	8
I don't consider wireless charging as "energy self-sufficiency", but large-scale availability of wireless power will make it feel as if it was.	7
Disconnected products are useless and therefore any self sufficiency is low value. Wireless solutions are obvious as well as energy harvesting but these do not imply self sufficiency.	6
Short- to medium-range wireless power transfer will charge mobile devices. Such a transfer will be mainly directed on the device itself rather than spread within the environment.	6
Devices become so small/thin/foils that they have no room for connectors, only radio waves (from light to wireless) interfaces with them.	3
Energy self-sufficiency rules out any form of energy made available with the purpose of using it in the device.	2
Very difficult to predict if or when ALL mobile and remote devices will be energy self-sufficient and wireless...	1



Average: 4.13 **Dispersion:** 0.81

Arguments regarding the relevance of R&I	**No. of votes**
Research is needed for energy harvesting of various types: solar, indoor lighting, vibrational, thermal, biological, chemical, electromagnetic.	76
Wireless Energy Transmission and Battery Management are promising research and innovation fields.	48
Promising research: self-sustainability and virtually perpetual operation of wireless networks.	19
Research is needed on solid-state high-energy and high-power density of micro-energy storage devices (batteries and supercapacitors)	12
One to three main harvesting mechanisms will dominate when mass market adoption takes place. Solar being one of the most likely winners.	11
Energy consumption of devices has to be driven to minimum: research in this area is as important as harvesting.	9
Processing power is further reduces by better chip technologies and integration	4
In case of wireless power transfer, the effects to organic tissues must be understood and regulated. Research should focus on highly directional beams from transmitters to receiver devices.	2
To allow AI to work with mobile devices, the facial, acoustic, etc. recognition algorithms need to work with compression artefacts	1
Graphene-based processors and graphene supercapacitors are a promising pathway to achieve this goal.	1

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It is 2040. Renewable Energy is available at competitive prices. More than half the electricity used for transport, housing and industry comes from renewable sources. A pan-European smart grid coupled with local micro-grids, with adequate storage facilities, ensures reliability of electricity supply. Hydrogen and biofuels complement the system. The sector is expanding to novel cultivations, such as algae and bacteria.

Studies and reports