

Titel van MJP:

EU SUNRISE Large Scale Research Initiative: Dutch contribution to Solar energy for the circular economy.

- o Bestaand programma voor continuering in KIC 2020-2023
- x Nieuw programma dat uitgewerkt moet worden

2. Tot welk(e) van de 8 cluster(s) van technologieën behoort dit MJP:

- x Advanced materials
- o Photonics and light technologies: plasmonics and cavity effects
- o Quantum technologies: quantum coherent control over chemical conversion
- x Digital technologies: High performance computing for *ex-ante* simulation of technology
- x Chemical technologies: Photochemical direct conversion
- x Nanotechnologies: responsive matrix materials for high yield conversion
- x Life science technologies: photobiological living catalysts
- x Engineering and fabrication technologies: Axiomatic design on the nanoscale

3. Welke sleuteltechnologie(ën) staa(t)n centraal:

- direct conversion of solar energy via integrated artificial photosynthetic systems
- direct conversion via biological and biohybrid systems
- electrochemical conversion driven by renewable power

4. **Positie NL:** the Netherlands belongs to the frontrunners in this domain. The Dutch Government and the Dutch Research Organisation NWO have invested in direct conversion of solar energy in the FES programme Biosolar Cells in which several Dutch universities cooperated. One of the results of this investment in the Dutch knowledge system is the European Commission has decided to explore a European Large Scale Research Initiative in this domain. Presently the Coordination and Support Action (CSA) of the EU SUNRISE Large Scale Research Initiative coordinated by prof.dr. H. de Groot (Leiden University) is developing a S&T roadmap, a community and a governance structure for the Large Scale Research Initiative Programme. The Netherlands is the tenth largest installer of existing Solar Energy technology (ca 2 G€/yr turnover) and has a front runner position in high tech production systems (250 M€/yr), in particular for thin film technology and integration in the existing technological infrastructure

5. Korte beschrijving van voorgesteld meerjarenprogramma voor onderzoek en ontwikkeling

The goal of the EU SUNRISE Large Scale Research Initiative is to provide the key enabling technologies to make sunlight and abundant molecules (e.g. H₂O, CO₂, N₂, O₂) the prime sources of energy and materials for modern society. This will be essential for facilitating the transition from a linear to a circular economy with huge benefits for society, the planetary ecosystems, the European economy and the ongoing efforts to mitigate climate change.

For direct conversion of solar energy via integrated artificial photosynthetic systems (TRLs 0-4) new solutions in the molecular photocatalysis domain are needed that offer high energy conversion efficiency and long-term stability and are based on materials and processes that are not too costly for upscaling. The overarching key technology gap is the bottom-up engineering of bio-inspired responsive nanomaterials for non-adiabatic

conversion of energy with near-unity yield. High Performance Computing (HPC) will be essential for the accurate simulation of innovative solutions prior to their experimental implementation.

For direct conversion via biological and biohybrid systems (TRLs 0-4) major breakthroughs will have to be made in genetic engineering of metabolic pathways for fuels and chemicals by applying emerging state-of-the-art synthetic biology technologies. In parallel, synthetic biology toolboxes will be combined with man-made solar energy conversion systems to engineer biohybrid systems to form complex organic compounds with high selectivity.

For electrochemical conversion driven by renewable power (TRLs 3-8), the bottlenecks to be solved, are in the field of development of suitable catalysts, e.g. finding stable and abundantly available catalysts, development of selective and stable catalysts for multi-electron/multi-proton reductive processes for direct CO₂ conversion. Furthermore the electricity generated via PV and wind must be integrated into the existing energy system, alongside distributed and dynamic chemical energy storage, with large scale electro-catalysis providing a mature technology that can be implemented.

6 Ecosystem: The EU ecosystem presently consists the Coordination and Support Action (CSA) of the EU SUNRISE Large Scale Research Initiative responsible for developing a S&T roadmap, a SUNRISE community and a governance structure (nine academic partners, three industrial partners, six research organizations and two alliances) and is coordinated by prof. dr. H. de Groot, Leiden University. Support has been obtained so far from >200 players from academia, industry, and society, including NGOs and global players in the energy, chemical and automotive sectors. (H. de Groot, personal communication).

The Dutch ecosystem consists of colleagues working in projects that received a grant from the NWO grant Solar2Products and related programs.

7. Organiserend vermogen: The government support for and the cooperation of NWO and several Dutch Universities (University of Amsterdam, Technical University Twente, Technical University Eindhoven, Leiden University, Wageningen University and Research) in the Biosolar Cells programme has created a strong base for follow up action. In addition to that the Solar to Products (S2P) programma initiated by TKI BBE and NWO further reinforces the base. To create an optimal interaction with the Biosolar Cells follow up at the European Level (see paragraph 4) coordination is with prof. dr. H.de Groot of the Leiden Institute of Chemistry.

8. Kans op maatschappelijke impact op korte en lange termijn:

The objective is to replace fossil fuels in the energy and chemical sector as quickly as possible using sunlight and readily abundant molecules (e.g. H₂O, CO₂, N₂ and O₂). On the long term this is the most radical if not the only solution to realize a more sustainable future for the inhabitants of Planet Earth that will have a huge impact on Planet, Profit and People. A shorter term effect will be on the production of electricity, fuels and chemicals produced via renewable power driven processes. This MJP can contribute to missions A (Fully CO₂ free electricity system by 2050), B(CO₂-free habitat by 2050), C (net climate neutral feedstock,

products and processes that are at least 80% circular) and D (zero-emission mobility for people and transport) of the table in the IKIA summary.

9.Kans op economische impact op korte en lange termijn:

Short term: PV+Electrolysis (TRL 8), longer term direct conversion (TLR 0-3). Willingness to invest is emerging with private partners and (European) regions depending on the TRLs and the estimated time at which impact in the market at a large scale is expected. (For the higher TRLs within 5 years, for lower TRLs 5-10 years and longer). In the context on innovation not only TRLs but also SRLs (Societal Readiness Levels) deserve attention.

10.Krachtenbundeling

SUNRISE Flagship Initiative partners and Dutch colleagues in Universities and research organisations active in the same domain (see also paragraph 7).

11. Cross-over karakter:

Energy and chemistry, ICT, PV and chemistry, predictive modeling in environmental/climate change; (axiomatic) industrial design at nanoscale and social sciences and ethics working on societally Responsible Innovation and Transitions and behavior.

12. Indicatie van benodigde gemiddelde jaarlijkse financiering en commitments voor periode 2020-2023: zie tabel

Estimate: ca 23 MEuro per jaar for NL will bring the program forward. (Dit betreft de schatting van Huub de Groot voor artificial leaves.)

Bron	Totaalbedrag	Waarvan gecommitteerd	Waarvan te mobiliseren
Private middelen	4.8	3.5	1.3
PPS toeslag	1.2	0.5	0.7
TO2 middelen	3.5	3	0.5
NWO	3	2	1
Universiteiten/hogescholen	1.0	0	1.0
Regionale middelen (provincie, gemeente)	1.4	1	0.4
Departementale middelen	5	1	4
EU middelen	2	1	1
ROMs en InvestNL	1	0	1
Anders, namelijk	0.1	0	0.1
Totaal bedrag (mln Eur per jr)	23	12	11

Noot bij de tabel: SUNRISE heeft een brede basis van >200 ondersteunende organisaties wereldwijd die verder zal worden uitgebouwd, in Nederland via NERA. In het proposal stadium hebben zich reeds gecommitteerd (met namen contactpersonen):

Universiteit Leiden:

H. de Groot

UL vertegenwoordigt de League of European Research Universities (LERU) met nog 2

NL leden: UVA (J. Reek) en UU (G. Kramer)

Avantium	G. Gruter
Differ	A. Bieberle
ECN	H. Jeeninga
Hydron Energy	S. ten Hoopen
InCatT B.V.	J. Reek
Innovation Quarter	R. Zonneveld
Metabolic	E. Gladek
Photanol	K. Hellingwerf
SCM Amsterdam	S. van Gisbergen
TU-Eindhoven	T. Noël
University Twente	J. Huijser
Everest Coatings	E. Maloney

Voorts zijn nauw betrokken Sunrise partner Siemens (M. Fleischer) en NWA partner Shell (F. Cassiola)

Daarnaast hebben een aantal private partijen uit de SUNRISE community verbanden met de Nederlandse onderzoeksgemeenschap die kunnen en zullen worden uitgewerkt voor een nieuw programma, onder meer SUNRISE partners Johnson Matthey (R. Potter) en Engie (J. Mertens), en de Europese supporters Toyota Motor Europe (H. Johnson), Solvay (J.-M. MAS), Covestro (T. Goergen), PEPPERPrint (F. Breitling), 3M (M. Solana), REPSOL (M. Alonso), Neste (L. Lindfors), Lafarge (M. Gimenez), Total (B. Pahlawan), SABIC (H. Idriss)