Innovation Contract Solar Energy

Towards Green Jobs

Building Our Solar Future

Wim Sinke and Albert Hasper
on behalf of the Innovation Table Solar Energy

15 February 2012

Verantwoording

Dit Innovatiecontract is tot stand gekomen door intensieve interactie tussen vertegenwoordigers van het Nederlandse bedrijfsleven op het gebied van zonne-energie, de Nederlandse onderzoekssector, de Nederlandse overheid en maatschappelijke organisaties.

De tekst is opgesteld onder verantwoordelijkheid van Albert Hasper en Wim Sinke, trekkers van de Innovatietafel Zonne-energie, met steun van Hein Willems (Solliance), Paul van den Avoort (HTS&M/TNO), Paul Pex (ECN), Dennis Gieselaar (Oskomera), Wiep Folkerts (SEAC), Jan Bultman (ECN), Wijnand van Hooff, Boukje Ehlen en Iwan van Bochove.

Verder is tijdens het proces steun verleend en advies gegeven door Jasper Reijnders (FOM), Bert Janson (AgentschapNL), Ed Buddenbaum en Bas Heijs (Ministerie van EL&I), Ad Schoof en Kenneth Heijns (ondersteuning Topteam Energie) en vele anderen.

Cover photo: John Sondeyker

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Motivatie en scope

Zonne-energie heeft een enorm potentieel: mondiaal, in Europa en in Nederland. Grootschalige toepassing van zonne-energie voor de productie van elektriciteit, warmte en -op termijn- brandstoffen kan een belangrijke bijdrage leveren aan vérgaande reductie van CO_2-emissies, aan het vergroten van voorzieningszekerheid, aan het voorkomen van uitputting van voorraden en aan rurale energievoorziening. De in december 2011 verschenen *IEA Solar Energy Perspectives* onderstreept deze enorme mogelijkheden en schetst een wereld waarin op termijn onder meer 50% van de mondiale, dan sterk gestegen elektriciteitsbehoefte wordt gedekt door zonne-energie. Dit Innovatiecontract focusseert op fotovoltaïsche zonne-energie (PV), inclusief gecombineerde opwekking van elektriciteit en warmte. Die sector is in Nederland sterk ontwikkeld en biedt bij uitstek kansen voor verdere innovatie en groei zowel aan de kant van de technologie als aan de kant van de toepassingen. De voor de energietransitie en de economie ook zeer belangrijke thema's Zonnewarmte & –koude en Zonnebrandstoffen zijn onderdelen van (onder meer) de Innovatiecontracten in de thema's Energiebesparing in de Gebouwde Omgeving en Gas. Op het niveau van de onderzoeksgroepen en –projecten wordt nauw samengewerkt op gebieden waar wetenschappelijke of technologische synergie met PV bestaat.

Dit Innovatiecontract Zonne-energie (Solar Energy) voor de Topsector Energie is opgesteld in nauwe samenwerking met de Topsector HTS&M onder een gezamenlijke roadmap. Financiering is voorzien vanuit beide Topsectoren en er wordt gestreefd naar de vorming van één TKI.

Het bedrijfsleven, vertegenwoordigd door partijen uit de hele waardeketen, heeft een bepalende rol gespeeld bij het vaststellen van de Innovatieagenda in dit Contract en een omvangrijk commitment afgegeven voor deelname en bijdragen aan de concrete programma's en projecten.

De betekenis van zonne-energie voor energie en economie In Nederland

Op dit moment staat in Nederland ongeveer 100 megawatt-piek (MWp) aan PV-systemen opgesteld en mondiaal 70 GWp. De opwekkosten van PV zijn in de afgelopen jaren sterk gedaald en liggen nu voor gangbare systeemtypen in Nederland op het niveau van de consumentenprijzen van grijze stroom. Bij de alom verwachte verdere daling van opwekkosten zullen daarom in het komende decennium omvangrijke zelfdragende markten voor PV kunnen ontstaan. Snelle groei van deze markten wordt gefaciliteerd door de ontwikkeling in dit Contract van de benodigde producten en diensten. De doelstelling van de sector voor 2020 is een opgesteld vermogen van 4 GWp, bij opwekkosten van 0,10-0,15 €/kWh. Dit komt overeen met een **bijdrage van 3% aan het totale elektriciteitsgebruik in 2020** en een **bijdrage van 10% aan de doelstelling voor duurzame elektriciteit**. Deze snelle groei wordt enerzijds mogelijk gemaakt doordat zonnestroom op consumentenniveau kan concurreren met conventionele opgewekte stroom en anderzijds doordat geschikte producten en diensten beschikbaar komen om deze klantgroep te bedienen. Overigens is 4GWp in 2020 in relatieve termen lager dan het vermogen *huidige* opgestelde vermogen in Duitsland. Na 2020 kunnen de kosten verder dalen tot ongeveer 0,05 €/kWh, zodat PV in de periode van 2020 tot 2030 ook zal kunnen concurreren in andere, professionele markten. Het potentieel voor PV wordt geschat op minimaal 90 GWp, zodat de doelstelling voor 2020 moet worden gezien als een eerste stap naar grootschalig gebruik, waarbij **PV ook in Nederland een substantieel deel van het totale elektriciteitsgebruik concurrerend kan opwekken.**

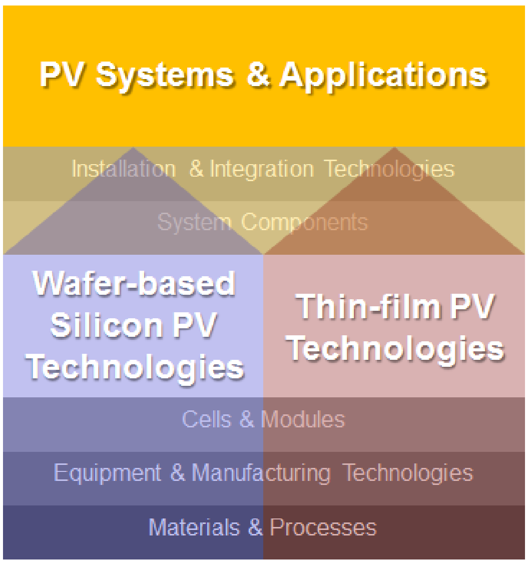
Grootschalige toepassing van PV in een dichtbevolkt land als Nederland is echter alleen mogelijk wanneer de systemen worden geïntegreerd in de gebouwde omgeving en de infrastructuur (meervoudig ruimtegebruik). Voor de gebouwde omgeving is zonne-energie tevens de enige duurzame energiebron die overal (locaal) en in grote hoeveelheden beschikbaar is. Een deel van dit Innovatiecontract richt zich daarom op die integratie, waarbij drastische prijsdaling hand in hand moet gaan met esthetische kwaliteit, duurzaamheid, veiligheid en een hoge energieopbrengst.

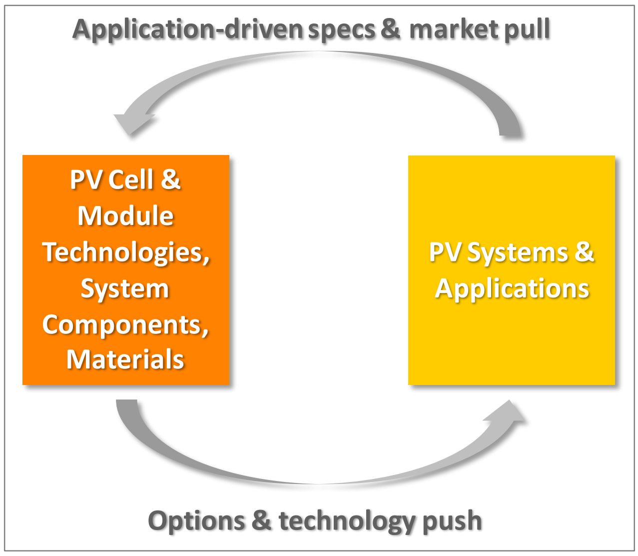
Een tweede voorwaarde voor grootschalig gebruik van PV is integratie in het elektriciteitsnet. Bij een toenemende penetratiegraad van PV worden het toepassen van intelligente elektronica, afstemming van vraag en aanbod en/of opslag technisch noodzakelijk, maar vanuit economisch oogpunt ook aantrekkelijk. Dat is het tweede focusgebied binnen dit Innovatiecontract.
De mondiale PV-sector is in het afgelopen decennium met gemiddeld 50% per jaar gegroeid. Hij heeft nu een omzet van 50 miljard euro en geeft werk aan 500.000 mensen. De Nederlandse PV-sector heeft een omzet van 700-800 miljoen euro en biedt werkgelegenheid aan 2100-2500 mensen zoals blijkt uit gegevens van 2010. Nederlandse machinebouw heeft meer dan 5% van de omzet van 10 miljard euro en enkele bedrijven zijn marktleider in hun segment. De kwaliteit van de Nederlandse kennis en technologie is zeer hoog en dit geeft mogelijkheden voor groei in deze uiterst competitieve markt. De doelstelling van de sector verenigd in dit Contract is dan ook om de omzet te laten toenemen naar **3-5 miljard euro in 2020, met 7.500-12.500 hoogwaardige banen**. Een belangrijk deel van die omzet is in de vorm van export. Ook hier zijn de mogelijkheden voor verdere groei na 2020 groot. Het **verdienpotentieel** in termen van overheidsinkomsten in de vorm van vennootschapsbelasting **is minimaal 100 miljoen euro per jaar**.

Innovatiethema's

Dit Contract richt zich op twee belangrijke dimensies van innovatie op het gebied van PV (zie ook de figuren):

1. **Systemen en -Toepassingen:**
   I. Fysieke integratie in gebouwen & infrastructuur
   II. Elektrische integratie;
2. **Technologieën:**
   I. Wafer-gebaseerde silicium PV-technologieën;
   II. Dunne-film PV-technologieën.





Het onderdeel PV-Systemen en -Toepassingen heeft een directe verbinding met de doelstellingen op het gebied van energie en draagt tevens bij aan de doelstellingen op het gebied van economie. Het onderdeel PV-technologieën biedt enerzijds directe input in de vorm van basiscomponenten voor PV-Systemen en -Toepassingen en heeft anderzijds een waarde op zichzelf als banenmotor en hightechsector bij uitstek. In beide onderdelen worden toepassingsgericht onderzoek en technologieontwikkeling gecombineerd met funderend onderzoek, met als doel om grensverleggende innovaties binnen de thema's mogelijk te maken, maar ook om voorbereid te zijn op de komst van nieuwe thema's of die zelf te kunnen agenderen.

De doelstellingen binnen de thema's zijn in detail uitgewerkt in het Innovatiecontract, maar laten zich als volgt samenvatten:

- Kostenverlaging van materialen, processen en eindproducten met als doel om de opwekkosten van PV te verlagen en zo grootschalig gebruik mogelijk te maken en om de internationale concurrentiepositie van het Nederlandse bedrijfsleven te behouden en te versterken;
- Prestatieverhoging van PV-cellen, -modules en -systemen, als universele hefboom voor kostenverlaging, maar ook om de elektriciteitsopbrengst te maximaliseren wanneer ruimte beperkt is;
- Mogelijk maken van grootschalige toepassing van PV door de ontwikkeling van producten en ontwerpconcepten voor integratie van PV in de gebouwde omgeving en de infrastructuur en voor integratie van PV in het elektriciteitsnet;
- Bereiken van integrale duurzaamheid van PV, onder meer door geschikte materiaalkeuze en hergebruik en vermindering van het energiegebruik in productie.

Behalve aan technische innovatie draagt PV ook bij uitstek bij aan **sociale innovatie**:

- Duurzaamheid: PV brengt het opwekken van duurzame energie letterlijk en figuurlijk dicht bij huis;
- Onafhankelijkheid/zelfstandigheid: individuen of groepen van individuen kunnen middels een PV-systeem zelf energie opwekken;
- Trend setting: het hightech karakter van PV, in het bijzonder van geïntegreerde systemen met aanvullende functionaliteit op het gebied van smart grids en energie-efficiënte gebouwen, kan een belangrijke groep van early adopters aantrekken en daarmee een voorbeeld geven voor een veel grotere groep in de samenleving.

Operationalisering van deze ambitie loopt via het actief betrekken (als lid) van vertegenwoordigers van consumentenorganisaties (o.m. Vereniging Eigen Huis en Consumentenbond), milieuorganisaties (o.m. SNM, WNF en Greenpeace) en brancheorganisaties (o.m. Holland Solar en UNETO/VNI) bij de Innovatietafel.

Het programma adresseert daarmee belangrijke **maatschappelijke en ethische vraagstukken**. Schaarste en uitputting van voorraden zijn speerpunten in het opgestelde programma zoals het inpassen van alternatieven voor schaarse materialen. Verder zijn *design-for-recycling* en *cradle-to-cradle* benaderingen een integraal onderdeel van het programma. Het programma is ook uitdrukkelijk gericht op het behouden of het verbeteren van de kwaliteit van de leefomgeving: meervoudig ruimtegebruik, esthetische kwaliteit en kleinschaligheid. Daarnaast worden binnen het programma belangrijke ethische vraagstukken geadresseerd, zoals door analyses van en communicatie over de mogelijke risico's van nanotechnologie en de wijze waarop de PV-sector daarmee omgaat. Verder is PV bijzonder geschikt om elektriciteit te brengen bij 1,5 miljard mensen in ontwikkelingslanden die het nu zonder netaansluiting moeten stellen. Tot slot, en wellicht het belangrijkst, is PV een technologie die geen wissel trekt op de mogelijkheden van toekomstige generaties; de definitie van duurzaamheid.

Nationale aanpak met regionale en internationale verankering

In dit Innovatiecontract bundelen de Nederlandse zonne-energiesector en de partijen daaromheen hun krachten. Daarbij speelt spelen regionale en internationale verankering echter een cruciale rol. Op het gebied van Systemen & Toepassingen slaan partijen de handen ineen in de grensoverschrijdende regio Limburg. Het recente initiatief **Building Integrated High Tech Systems** (BIHTS), waarin regionale private en publieke partijen samenwerken, werkt samen met het daaraan complementaire **Solar Energy Application Centre** (SEAC); een initiatief van onder meer ECN en TNO. Op deze wijze ontstaat een krachtige groep spelers die in nationaal én internationaal verband kunnen opereren. Een **proeftuin** voor gebouwgeïntegreerde PV vormt hiervan een onderdeel. Hierbij is het overigens nadrukkelijk de bedoeling om samenwerking te zoeken met partijen in andere delen van het land.

Op het gebied van dunne-film PV-technologieën speelt het samenwerkingsband **Solliance** in de wijde regio rondom Eindhoven een centrale rol. In Solliance werken TNO, ECN, TU/e, Holst Centrum en het Belgische Imec reeds samen, maar er wordt actief gewerkt aan integratie met activiteiten van andere sterke spelers in Nederland en Duitsland. Op het gebied van wafergebaseerde siliciumtechnologie is de vorming van het **Silicon Competence Centre** (SCC) een belangrijke stap naar verdere nationale bundeling van krachten en essentieel voor uitbouw van het mondiale succes van Nederland op dit terrein.
Het Nederlandse innovatieprogramma op het gebied van zonne-energie is volledig ingebed in internationale initiatieven en in het bijzonder het **Solar Europe Industry Initiative** (SEII), feitelijk de Europese tegenhanger van dit Innovatiecontract. Het SEII is een van de innovatiepijlers onder het Europese Strategic Energy Technology (SET) Plan. Nederlandse partijen spelen een cruciale rol bij de vormgeving en uitvoering van het SEII.

Relatie met andere innovatiegebieden en sectoren

Het werkterrein van dit Innovatiecontract heeft sterke verbanden met Intelligente Netten enerzijds en Energiebesparing in de Gebouwde Omgeving anderzijds. Dit Contract omvat alle aspecten van PV-systemen ten en met de elektronica voor netkoppeling en PV-bouwelementen. Juist op die grensgebieden zal intensieve samenwerking worden gezocht. Enkele deelnemende bedrijven zijn actief binnen meerdere gebieden. Verder is er de belangrijke koppeling met HTS&M. De doorsnede door de PV-sector binnen het Innovatiecontract van HTS&M loopt primair langs de lijnen van de enabling technologies (de horizontale doorsnedes in de linkerfiguur), terwijl dit Innovatiecontract is ingedeeld naar de eindproducten en toepassingen.
De grootschalige inzet van PV vraagt een aanpak op het niveau van het totale elektriciteitssysteem, of zelfs energiesysteem. Daarom is de ontwikkeling van een integrale visie van groot belang, zodat de ontwikkelingen op de deelgebieden van de Topsector Energie op elkaar kunnen worden afgestemd en elkaar kunnen versterken. Een deel van de deelnemers in dit Contract richt zich in het bijzonder op aspecten die met zo'n integrale aanpak samenhangen. Daarnaast is er ook op het niveau van gebouwen en wijken behoefte aan zo'n integrale aanpak omdat PV is altijd een onderdeel van een groter systeem.

Partners en bijdragen

Ruim 60 bedrijven over de hele PV-waardeketen van materialen en productieapparatuur tot en met systeemtoepassingen hebben zich verbonden aan dit Innovatiecontract en toegezegd daaraan een bijdrage te leveren. De totale waarde van deze private bijdragen is meer dan **100 miljoen euro**. Dit geeft een brede en solide basis aan dit Innovatiecontract en een privaat/publieke financieringverhouding van 45%/55%. Een groot deel van de bedrijven heeft nu een harde Letter of Commitment afgegeven met realistische investeringen in concrete projecten, getekend door de verantwoordelijke functionarissen binnen de bedrijven. Dit is gelukt binnen 2 maanden na het verzoek van het Topteam op 15 december. Dit geeft de enorme inzet en commitment weer van de Nederlandse PV-industrie. Deze groep van bedrijven omvat alle belangrijke spelers op het gebied van PV in Nederland en is representatief voor het hele veld. Meer dan de helft van de bedrijven behoort tot het MKB.
De kennispartners in dit Innovatiecontract vertegenwoordigen de hele kennisketen van funderend onderzoek (FOM en universiteiten) tot en met technologieontwikkeling en applicaties (ECN, TNO, hogescholen). De rol van de kennispartners is concreet beschreven en begroot in de programma- en projectbeschrijvingen, inclusief de voorgestelde financieringsbronnen.

Organisatiestructuur

De zonne-energiesector heeft de intentie om één gezamenlijk Topconsortium Kennis en Innovatie (TKI) met geschikte (deels reeds bestaande) substructuren te vormen[1]. Een voorstel voor de bijbehorende organisatiestructuur is uitgewerkt in het Contract. De (geformaliseerde) Innovatietafel Zonne-energie vormt een belangrijk onderdeel op sectorniveau. Het TKI is een open structuur waar partners kunnen toe- en uittreden, uiteraard rekening houdend met de voorwaarden die in de TKI-overeenkomst zijn geformuleerd.

Legitimiteit van de overheidsbijdrage

Nederland heeft een uitstekende kennis- en technologiepositie op het gebied van PV. Dit blijkt uit de mondiale klantenkring van bedrijven en onderzoeksinstellingen, maar ook uit de Nederlandse innovaties die belangrijke trends hebben gezet of inmiddels wereldstandaard zijn. Deze positie is opgebouwd door de inzet van ondernemers en onderzoekers en met consequente steun van de Nederlandse en Europese overheden. Nu de PV-sector geleidelijk de terawatt-schaal bereikt en “het echte werk” begint is het belangrijk om deze positie te behouden of zelfs uit te breiden. Omdat alle toonaangevende landen actieve overheidssteun voor hun PV-sector hebben, is het van essentieel belang dat de Nederlandse overheid voor een “level playing field” zorgt en de sector ook steunt. Deze steun is een economisch verantwoorde investering, omdat er een hoge return on investment behaald zal worden.

[1] De feitelijk vorming is afhankelijk van de mogelijkheden die daarvoor binnen de Topsector HTS&M worden gecreëerd (een besluit over de scope van TKI’s is daar nog niet genomen).

Rationale & scope of this Innovation Contract

Solar energy has a very large potential to provide cost efficient energy. Moreover, when properly designed, manufactured and applied, it is renewable ánd fully sustainable[2]. It can be harvested everywhere in different system sizes, from milliwatts to gigawatts. Solar energy plays an important role in all energy scenarios. Just recently, it was selected for the first in-depth technology review by the International Energy Agency[3], which covers solar energy for generation of heat (and cold), electricity and fuels. The latter is not to be confused with fuels from biomass. The review confirms the vital role of solar energy for a sustainable energy future, contributing to reduction of CO_2 emissions, security of supply, access to energy in the developing world and avoidance of resource depletion, see Figure 1. Solar energy systems for generation of heat and electricity are commercially available, but solar fuel generation systems are not yet on the market. Actually, the IEA Solar Energy Perspectives is the first authoritative document to include solar fuels as an option for large-scale future use.

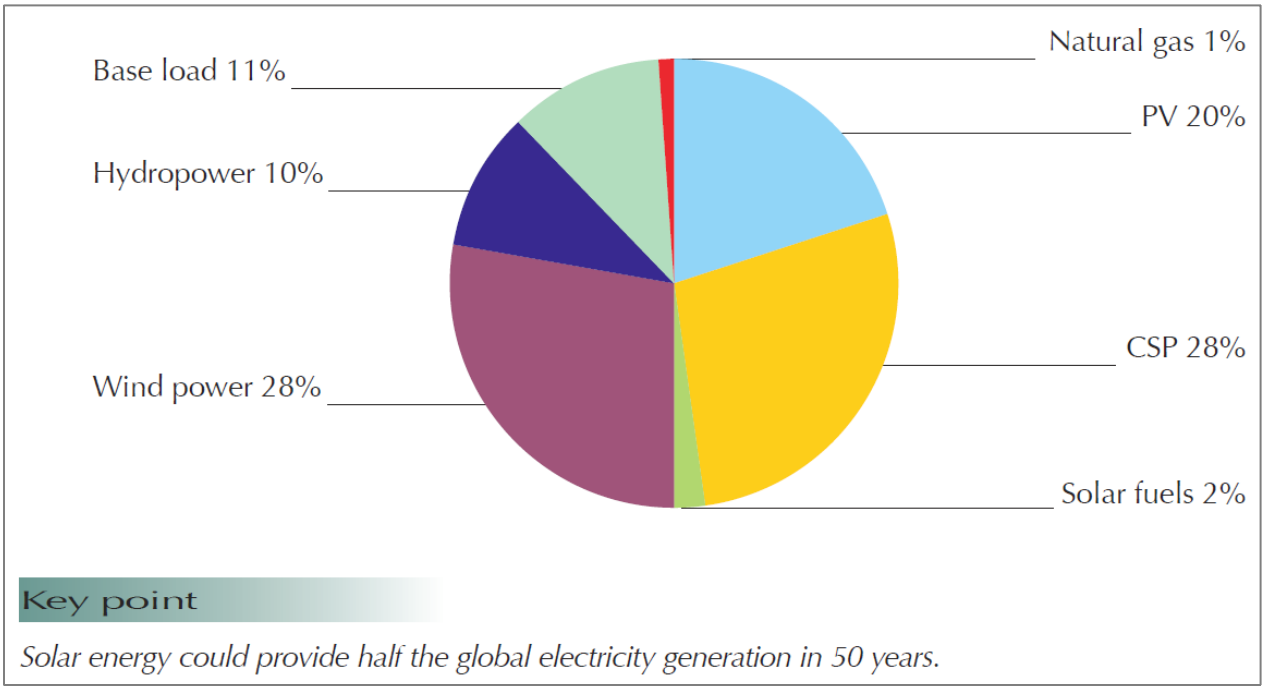


Figure 1: ***Global electricity generation by technology: possible long-term mix***
(source: IEA Solar Energy Perspectives, IEA, December 2011).

Because solar systems can be easily integrated into buildings and other objects, solar energy is well suited for use in densely populated areas and countries such as The Netherlands. It is the *only* sustainable energy source that is readily available locally in large quantities in the built environment and therefore a key technology for the Netherlands. The competitive position of solar energy, and in particular of photovoltaic solar energy (PV) for electricity generation, has been improved rapidly over the past 5 to 10 years, and it is expected that electricity from PV systems can compete in substantial parts of the total global electricity markets (i.e. not just on retail level) within a decade[4,5], allowing the formation of large, self-sustained markets. Already today, "grid parity" on consumer level has been reached in The Netherlands, meaning that PV system owners can earn back their financial investment with net metering only.

2 "Sustainability" has many different aspects, including supply chain security,

3 *Solar Energy Perspectives,* IEA, December 2011, see www.iea.org.

4 *Solar photovoltaics competing in the energy sector,* EPIA, 2011, see www.epia.org.

5 *SunShot Initiative*, US Dept. of Energy, 2011, see http://www1.eere.energy.gov/solar/sunshot/.

The Netherlands has a strong position in PV, which is the focus area of this Innovation Contract. Moreover, The Netherlands is building up world-class research capacity in the field of solar fuels, which has been selected as a strategic priority area by the Foundation for Fundamental Research on Matter (FOM). This important topic, which also has relations with Concentrating Solar Power (CSP), is primarily covered in the Innovation Contract P2G/G2E. Several research groups involved in solar fuels, however, are also well represented in this Innovation Contract, which enables the achievement of synergies in research on important shared scientific challenges (e.g. related to advanced light management). Solar fuels are also a subject in the Shell-NWO Public-Private Partnership (PPP) “Computational Sciences for Energy Research”. Because of its broad scope and multidisciplinary character this PPP is considered important for this Innovation Contract as well. CSP for electricity generation is not part of this Innovation Contract because this technology is not suited for use in our country (it requires a large fraction of direct sunlight) and few Dutch companies are active in this field. Solar thermal energy is an essential element of the technology portfolio for the built environment and is covered in the Innovation Contract Energy Efficiency in the Built Environment. Combined generation of heat and electricity in PV-thermal (PVT) hybrid systems, however, is included in this Innovation Contract.

As part of dynamic portfolio management, the scope and contents of this Innovation Contract will be monitored and steered continuously. Therefore new technologies and topics may be added in coming years when this is warranted by developments in research, industry or applications.

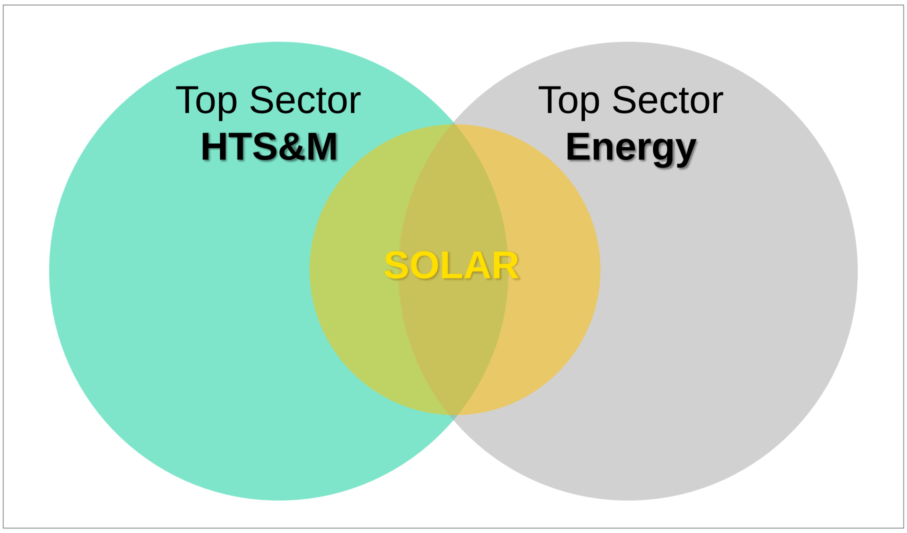


Figure 2: ***Solar energy is part of two Top Sectors.***

This Innovation Contract has been developed in close cooperation the Top Sector High Tech Systems and Materials (HTS&M), which shares the focus area “Solar Energy” (an in particular PV) with the Top Sector Energy. Where possible in view of the stage of the development of Contracts in HTS&M, this Innovation Contract describes the respective roles of Energy and HTS&M (i.e. envisaged funding).

1 Vision & Strategy

1.1 Present

1.1.1 Current situation: well positioned for innovation and growth

Photovoltaic solar energy (PV) has experienced rapid global market growth and price reduction over the past decades. The installed capacity by the end of 2010 was approximately 40 gigawatt-peak (GWp), see Figure 3. In 2011 this has grown to ≈67 GWp[6], with turn-key system prices typically in the range of 3 to less than 2 €/Wp (down to 1.6 €/Wp in some cases). Higher prices correspond to dedicated systems adapted for, or integrated into buildings; lowest prices are for standard rooftop or ground-based systems in mature markets. Generation costs (levelized cost of electricity) are now 0.10 – 0.30 €/kWh, depending on geographical location, system type and market maturity. In The Netherlands ≈100 MWp of PV systems are installed and generation costs are 0.20 - 0,30 €/kWh for common system types.

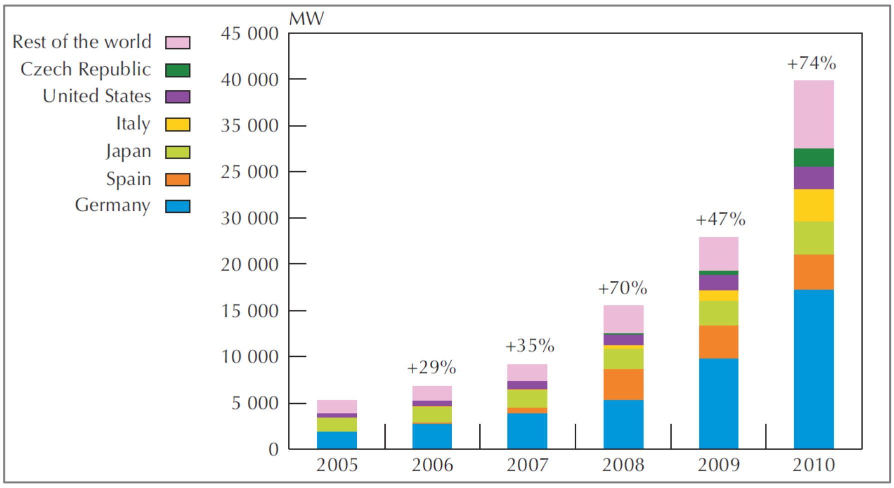


Figure 3: ***Global cumulative installed PV capacity (source: Solar Energy Perspectives, IEA, 2011).***

The 2011 contribution of PV to the electricity consumption is still very small in all parts of the world, with the exception of Germany, where it has reached 3%. This situation is expected to change rapidly as PV soon reaches grid parity on different price levels in the coming decade and self-sustained markets will form (see section 1.2) since system owners can have a positive return on their investment without support in the form of subsidy or feed-in tariff.

[6] *Market Report 2011*, EPIA (2012), www.epia.org.

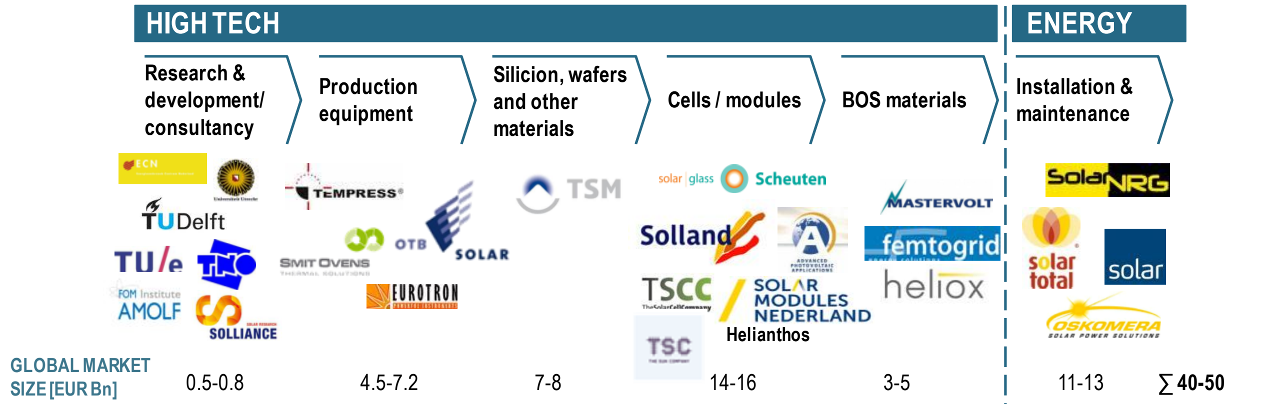
Figure 4: ***City of the Sun (photo taken during the construction phase, 2009), Municipality of Heerhugowaard.***

The Netherlands has played a pioneering role in developing innovative PV-solutions for buildings and infrastructural objects (e.g. sound barriers), which are expected to be the main application forms for densely populated countries. The Netherlands was also one of the first countries to demonstrate a large number of PV systems fully integrated into a newly built zero-emission urban area (City of the Sun, Municipality of Heerhugowaard), see Figure 4. When commissioned it was even the biggest project in its kind worldwide (>5 MWp in total). This and other projects have yielded valuable and unique experience about integration of PV, into buildings, other objects and integration into the electricity grid. The absence of a market incentive for PV has led to new business models and technologies for a self-sustained market for PV in the Netherlands. These factors place The Netherlands in an excellent position to develop and deploy innovative PV systems in large volumes over the coming decade and in the longer term.

The Netherlands has a strong and even leading position in PV technology, i.e. advanced PV cells, modules and other system components, particularly in combination with industrial processes and production equipment. The total innovation chain, from research on novel materials, processes and devices, through industrial manufacturing technology and equipment to system applications is present in our country. 150 to 200 Dutch companies are active along the value chain for PV, with a total turnover of 700 to 800 million euro[7]. The sector provides jobs for 2100-2500 people (fte). The PV sector is second in size in the field of renewables[8]. Note that all data refer to 2010. More than half of the present turnover is realized in equipment manufacturing (>500 million euro in 2010), almost entirely for export. The worldwide market share of the Dutch equipment manufacturers is >5% of a total market of 10 billion euro in 2010. The competitive position of the Dutch industry is strong: it is supported by a world class knowledge position of Dutch research institutes and universities in PV, and it benefits from synergies with existing sectors such as the semiconductor-, optical media-, printing-, mechatronics-, glass- and chemical industry. This same supply chain finds an additional market (or new focus) in solar technology.

[7] *A Vision for the PV Sector – update April 2011,* Roland Berger. Input document for the Top Team Energy.

[8] *Versterking van de Nederlandse Duurzame Energiesector*, Ecorys, 2010.



	Research & development/ consultancy	Production equipment	Silicion, wafers and other materials	Cells / modules	BOS materials	Installation & maintenance	
GLOBAL MARKET SIZE [EUR Bn]	0.5-0.8	4.5-7.2	7-8	14-16	3-5	11-13	∑ **40-50**
TURNOVER NL [EUR m]	30-35	250-300	-	350-375	50-75	25-50	∑ **700-800**
MARKET SHARE NL [%]	4.5-6%	4-5.5%	-	2-2.5%	1.5-2%	0.2-0.4%	∑ **1.6-1.8%**
EMPLOYEES NL [FTE]	200-250	700-750	5-10	900-1,000	225-250	100-200	∑ **2,100-2,500**

Figure 5: ***the Dutch PV solar energy sector in key figures (adapted from: A Vision for the PV Sector – update April 2011, Roland Berger. Input document for the Top Team Energy).***

1.1.2 On-going actions

The Dutch PV solar energy sector has recently made important progress in building and strengthening its innovation ecosystem, in the fields of Discovery, Development and Deployment.
In the field of *Discovery*, a number of dedicated research programs (i.e. instead of a set of individual projects) has been defined and is now being carried out:

- Joint Solar Program: Industrial Partnership Program of FOM and Shell (phase 1) and Nuon Helianthos (phase 2) for basic research on novel PV conversion approaches, solar cell device designs and processes;
- NanoNextNL: national program for R&D on nanotechnologies, which includes a subprogram dedicated to PV and related enabling technologies;
- Advanced Dutch Energy Materials Innovation Lab (ADEM): joint materials research and investment program of ECN and the 3 Dutch Universities of Technology (Delft, Eindhoven and Twente), which includes a theme (materials for) PV;
- FOM Focus Groups: multi-annual research programs (research groups), 2 of which are in the field of PV and related topics (at FOM-AMOLF and Groningen University, respectively).

These programs, in combination with individual projects and project clusters financed through generic programs, provide an excellent basis for the Development phase.

A major achievement related to the *Development* phase is the definition and publication of the joint roadmap *Zon op Nederland*[9], focussing on challenges and opportunities related to materials, equipment & processes, advanced devices and novel applications. This Innovation Contract is fully consistent with this Roadmap and a vehicle for achieving its targets.

Another major step forward related to both *Discovery* and *Development* is the recent establishment of Solliance, the alliance of thin-film PV R&D organisations in the Eindhoven-Leuven-Aachen region[10]. Solliance aims to put this region on the map as a world player in the field of thin-film solar cell and module manufacturing technology. In order to achieve this, Solliance brings about synergy between the strong players in the region: industry, research institutes and universities. This existing organisation is fully

[9] *Zon op Nederland*, 2011, see http://www.egmedia.nl/roadmap.pdf
[10] Current Solliance partners are TNO, ECN, Eindhoven University of Technology, Holst Centre (all NL) and imec (BE).

integrated into the governance structure of the Top Consortium Knowledge and Innovation ("TKI") Solar Energy proposed in the Innovation Contract, thus avoiding any duplication and enhancing efficiency.

An action at the interface between *Development* and *Deployment* is the establishment of the Solar Energy Application Centre (SEAC), an alliance initiative of TNO, ECN and Zuyd University of Applied Sciences, focused on bundling and development of knowledge about the applications of (PV and thermal) solar energy systems, in the built environment, infrastructure and networks, including their mechanical and electrical integration. SEAC cooperates with the cross-borders regional initiative for a knowledge infrastructure BIHTS (Building Integrated High Tech Systems), in which the Province of Limburg, Parkstad Limburg, Municipality of Heerlen, Stadt Aachen, a renowned test and certification company, LIOF, Technical University Aachen (RWTH) and Zuyd University of Applied Sciences bundle their expertise. SEAC aims to be the bridge between research and technology development on the one hand and large-scale application of advanced (in particular, but not only) solar energy systems on the other hand. The scope of their activities covers the part of the solar energy supply chain starting at and downstream from the solar module or collector. This part of the supply chain (systems, building integration products, grid integration products) has clear regional (e.g. Western Europe) features due to building practices, grid characteristics, etc., and therefore benefits from dedicated initiatives like these.

Another important action on the interface between *Development* and *Deployment* is in the field of integration of PV into the built environment. Through the Small Business Innovation Research (SBIR) program, supported by AgentschapNL, four proposals of companies in the field of solar energy systems and applications have been approved.

An important action related to *Deployment* is the definition under the auspices of KEMA of a "National Action Plan"[11], focussing on large-scale implementation of PV in The Netherlands in the period 2012 - 2020. Moreover, the Dutch Solar Industry Association Holland Solar, in cooperation with UNETO-VNI (the association of companies in the field of technical installation and related end user sales) and AgentschapNL has developed a Master Plan Solar Energy[12], which is currently being carried out. It addresses the following topics:

- Installation guidelines and best practices;
- Education and training;
- Quality labelling and assurance (also part of the corresponding Green Deal).

1.1.3 Existing cooperation networks

The Dutch PV solar energy sector has joined forces and formulated common targets and approaches in all parts of the innovation chain. Important existing networks (see also previous paragraph) are:

- Thematic networks connecting specialists from research and industry in a specific field of science and technology from the different programs described in 1.1.2;
- The network and companies in Solliance, aimed at joined development of thin-film PV technologies and cross-cutting technologies for thin-film PV;
- The group of partners in SEAC, aiming at (o.a.) providing RD&D services for companies active in the downstream part of the PV value chain;
- The network of companies in PV that has, among others, taken the initiative to develop the aforementioned Roadmap *Zon op Nederland* and the *Vision for the PV Sector*.
- The network of companies active in deployment of PV, organised in the Section PV of Holland Solar.
- Cooperation between SEAC and BIHTS.

[11] *Nationaal Actieplan Zonnestroom*, 2011, see http://www.kema.com/nl/Images/Nationaal%20Actieplan%20Zonnestroom.pdf.
[12] *Masterplan Zonne-energie*, KEMA and partners, 2009.

1.2 Vision & ambition

The Dutch PV sector will create about 10,000 high tech jobs and generate an annual turnover up to 4 billion euro as well as 100 million euro in corporate tax in 2020 by executing this Innovation Contract. As a first step to very large-scale deployment, in 2020 3% of electricity will be generated using PV systems employing knowledge and/or technology developed in this Innovation Contract. In 2030 electricity from PV will be competitive with a major part of all electricity consumed in the Netherland (consumer, commercial and industrial), allowing a post 2020 growth to a share of at least 25%, aided by developments in Smart Grids, Energy Efficiency in the Built Environment, Solar Fuels, and other sectors.

1.2.1 Vision

The vision of the global PV sector is to develop technology that is flexible, reliable, affordable (competitive), and sustainable[13], and to achieve deployment on a terawatt scale a soon as possible (i.e. typically from 2020 on), as needed for impact. Moreover, the sector's Vision is to become one of the leading high-tech sectors of the 21st century, providing millions of jobs (currently about 500,000) throughout the value chain. This shared vision is illustrated in an excellent way in the recently published IEA Solar Energy Perspectives[14]. It sketches a bright future for PV and other solar energy technologies, with a contribution of up to 50% to the total global electricity consumption. The PV capacity would then be 12 to 15 TWp and generation costs in sunny regions down to 0.03 €/kWh (in The Netherlands down to 0.05-0.06 €/kWh).

The vision of the Dutch PV sector joined in this Innovation Contract is in line with this global vision and has two elements, related to the manufacturing industry (equipment, cells, modules, system components, materials, etc.) on the one hand, and deployment of PV on the other hand.

The **Industry Vision** is to strengthen and expand its position as a leading global supplier of advanced manufacturing technologies (materials, processes and equipment) for high-performance PV cells, modules and system components, in the rapidly growing global market. In addition the vision is to develop and supply solutions for new PV applications (architectural integration, physical infrastructure, automotive, greenhouses, etc.). By realising this vision, the PV industry sector will create 7,500-12,500 high-tech jobs and generate a turn-over of 3-5 billion euro by 2020[15], mostly in the form of export. The industry will build on the strong starting position in the field of PV technology, but it will benefit in particular from the presence of a large number of excellent SME's and multinational companies in the fields of semiconductors, high-tech equipment, advanced materials, innovative building, and more. Since 2020 only marks the start of the growth of the global PV sector to the terawatt-scale, there is ample opportunity for further growth after 2020. The period until 2020, however, is crucial to position The Netherlands as a key player in this highly competitive global sector, since it is the transition period from incentive-driven markets to self-sustained markets.

Although 2011 has been, and 2012 is expected to become a troublesome year for the upstream part of the global PV sector[16], longer-term growth perspectives are excellent since very large scale deployment of PV will take place beyond any reasonable doubt, as illustrated by the aforementioned IEA Solar Energy Perspectives and a range of other visions, scenarios and roadmap. The challenge for this part of the PV sector is to use the current shake-out period to develop the innovations that are essential to compete when market conditions are better again.

The **Deployment Vision** is to achieve large-scale application of PV systems in The Netherlands, such that PV makes a significant contribution to policy targets related to renewable energy and emission reduction. As a

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[13] See, for instance: *Strategic Research Agenda for Photovoltaic Solar Energy Technology – Edition 2011*, European Photovoltaic Technology Platform, www.eupvplatform.org.

[14] *Solar Energy Perspectives,* IEA, December 2011, see www.iea.org.

[15] *A Vision for the PV Sector – update April 2011,* Roland Berger. Input document for the Top Team Energy.

[16] This is due to several factors, in particular oversupply and forward pricing due to an expansion of global production capacity that was even faster than the growth of market demand, and the financial crisis which severely limited the availability of capital in Western countries.

first step, the Vision is to enable installation of at least 4 GWp of PV systems by 2020[17], thus contributing ≈3% to the total electricity consumption and ≈10% of the 2020 target for renewable electricity. This volume will roughly bring The Netherlands on the expected EU average by 2020 (top 5 countries aim 2-3 times more per capita). Our vision is that this volume is needed as a stepping stone towards full realization of the PV potential for the Netherlands, which is ≈90 GWp, or ≈75 TWh of electricity generation[18] for the built environment alone. This represents more than one third of the electricity consumption, assuming it is to double by 2050.

The Deployment Vision is fully based on the projected drop in turn-key system prices and generation costs. System prices are expected to go down from ≈2-3 €/Wp (the range corresponding to different system types and sizes) to ≈1-1.5 €/Wp in 2020 and to ≈0.5-1 €/Wp in the longer term. This price decrease will allow PV systems to compete in an increasing part of the electricity markets[19]. Applying the concept of "dynamic grid parity" (see Figure 6), PV will become competitive with retail electricity markets well before 2020 in all European countries[20], see *Figure 7*. Note that the assumed PV revenues in this model are modest compared to the actual situation in The Netherlands (i.e. they include avoided cost of purchase plus sales to the grid *at commercial rates*, whereas "net metering" is allowed in The Netherlands). Assuming net metering, grid parity has already been reached in The Netherlands for typical systems today[21]. This is a first, though very important step towards competitiveness other important electricity market segments.

It is expected that roughly half of the regional market for PV in 2020 will be building-*integrated* PV (BIPV), as opposed to building-applied or building-adapted PV (BAPV). Reasons for this are: (1) the multi-functionality of BIPV in the building envelope is expected to change the cost assessment of PV to a substantial extent, favourable for BIPV; (2) the regulation roadmap on energy consumption in newly-built housings (leading to energy neutrality in 2020) is a strong motor for applying BIPV in newly-built projects and in renovation programs.

Competitiveness is analysed by comparing PV's generation cost with the PV revenues (dynamic grid parity) and/or with the generation cost of other electricity sources (generation value competitiveness).

"Dynamic grid parity" is defined as the moment at which, in a particular market segment in a specific country, the present value of the long-term revenues (earnings and savings) of the electricity supply from a PV installation is equal to the long-term cost of receiving traditionally produced and supplied power over the grid.

"Generation value competitiveness" is defined as the moment at which, in a specific country, adding PV to the generation portfolio becomes equally attractive from an investor's point of view to investing in a traditional and normally fossil-fuel based technology.

Figure 6: *definitions in relation to the competitive position of PV*
***(source: Solar photovoltaics competing in the energy sector,* EPIA, 2011)**

[17] *Masterplan Zonne-energie*, KEMA and partners (Alliander, BOM, DSM, ECN, Energy Valley, Enexis, Municipality of Amsterdam, IBC Solar, KNCV, Mastervolt, NXP, Solen Energy, Scheuten Solar, City Region Arnhem/Nijmegen), 2011.

[18] *Naar een schone economie in 2050: routes verkend. Hoe Nederland klimaatneutraal kan worden., PBL and ECN, 2011, see* http://www.ecn.nl/docs/library/report/2011/o11076.pdf.

[19] *Solar photovoltaics competing in the energy sector,* EPIA, 2011, see www.epia.org.

[20] Differences in estimates are often related to different parameters used for the cost of capital and thus, to the total cost of ownership of the PV system, as well as to different assumed revenues.

[21] *Policies and opportunities for grid parity of PV in The Netherlands,* ECN Policy Studies, January 2012; and Natuur & Milieu, see www2.natuurenmilieu.nl/home/.

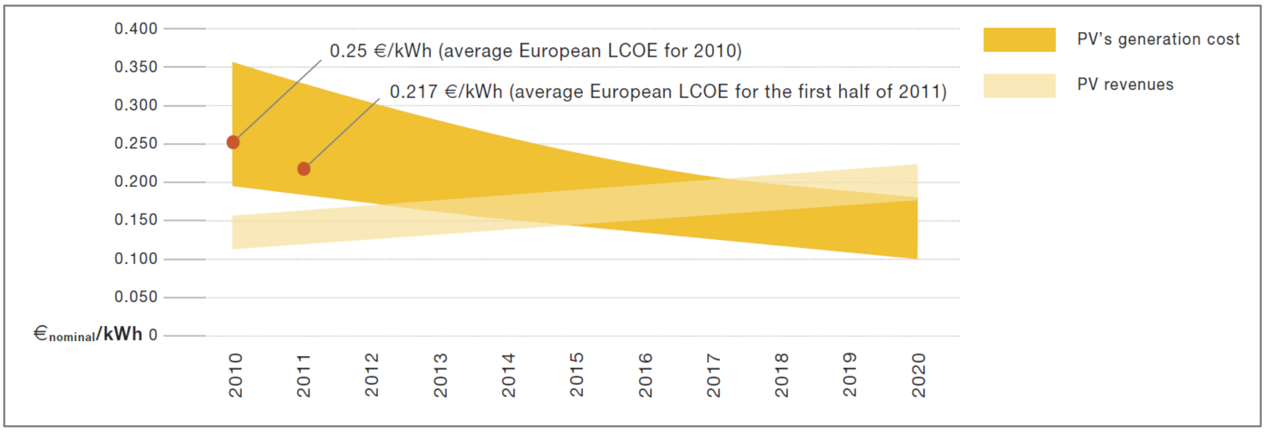

Figure 7: ***competitive position of electricity generated by residential PV systems in Europe (source: Solar photovoltaics competing in the energy sector, EPIA, 2011)***[22]

1.2.2 Ambition

In 2010 the Dutch PV industry had a combined turnover of 700-800 million euro, capturing ≈2% of a global market of some 50 billion euro. As the industry is at the start of an impressive growth phase, PV turnover is expected to grow to 100 – 200 billion euro or even more by 2020[23,24], resulting from a typical volume increase by a factor 4 to 8 combined with a price decrease by a factor 2. This Innovation Contract aims to further strengthen the Dutch PV industry in terms of innovation and competitiveness and to achieve a turnover of 3 to 5 billion euro by 2020[25], providing jobs to 7500-12500 people. The Dutch industry expects to capture a market share of 5-10% in production equipment and a significant market share in specialty materials and systems, high-end and application-dedicated PV modules, and Balance-of-System (BoS) components (3-5%). Our PV sector capitalizes on three factors:

- The recent emergence (and expected rapid growth) of self-sustained markets for PV systems, which offers important opportunities for developing and marketing of new products and services;
- The strong market position in production equipment;
- The excellence of our public & private knowledge infrastructure to couple equipment, processes and materials into new concepts & technologies.

Related to these factors, the ambition of the Dutch PV sector is to strengthen and expand its position in the fields of:

1. PV systems & Applications
   - *Physical Integration*
   - *Electrical Integration*

Ambition is to develop technologies and solutions that enable very large scale deployment of PV systems in The Netherlands on the one hand and form attractive export products on the other hand. The ***focus*** is on systems integrated in the built environment and the infrastructure.

2. Wafer-based Silicon PV Technologies
   - *Enabling industrial manufacturing technologies*
   - *High-performance PV modules*

[22] See definitions in Figure 6 (PV (source: Solar photovoltaics competing in the energy sector, EPIA, 2011). LCOE = levelised cost of electricity generation.
[23] *Solar Generation 6*, EPIA & Greenpeace, 2011, see www.epia.org.
[24] *The photovoltaic reality ahead: terawatt scale market potential powered by pico- to gigawatt PV systems and enabled by high learning and growth rates, Ch. Breyer, Proc. 26th EUPVSEC (2011).*
[25] Numbers updated from *A Vision for the PV Sector – update April 2011,* Roland Berger. Input document for the Top Team Energy.

Ambition is to develop world-class manufacturing technologies and high-end (very high efficiency, low cost) PV modules that strengthen the current position of Dutch companies and institutes as leading suppliers for the highly competitive and rapidly innovating global PV sector. The ***focus*** is on novel device architectures and an integrated approach towards cell and module design and manufacturing.

3. Thin-film PV Technologies
    - *Inorganic thin-film PV technologies (including novel high efficiency approaches);*
    - *Organic (polymer) PV*

Ambition is to develop materials, device designs and high throughput manufacturing technologies for ultra-low cost PV modules, and to enable new PV applications based on unique properties of specific thin-film technologies. The ***focus*** is on roll-to-roll processing and on products with added value over electricity generation only (e.g. multifunctional modules). Another ambition is to develop novel high efficiency solar cells, particularly for use in concentrator systems. ***Focus*** is on demonstrating the industrial feasibility of advanced III-V semiconductor devices.

Specific ambitions are laid down in the programs and projects detailed in Chapter 2.

1.3 Strategic innovation and long-term knowledge agenda

1.3.1 Market opportunities

Market opportunities in the broad field of PV solar energy coincide with addressing some of the main societal, economic and scientific challenges the world faces:

- *Building an economy based on new growth sectors:*
    - Developing world-class knowledge and technology in key, and therefore highly competitive areas, fully utilizing the opportunities offered by nanotechnology and other fields of science;
    - Ensuring that Europe and The Netherlands stay fully connected with Asia and the USA in the major high-tech sectors: renewable energy (with a prominent position of PV), energy storage, energy efficient lighting, smart energy grids, etc.;
      → develop the Dutch PV sector according to the Vision outlined in the foregoing.

- *Transforming the energy system into a (more) sustainable one:*
    - Drastically reducing CO_2 emissions;
    - Ensuring security of supply;
    - Providing access to energy in developing countries;
    - Avoiding depletion of energy resources;
      → large-scale deployment of PV through high-quality, affordable system solutions.

- *Ensuring public support for major changes:*
    - Demonstrating the attractiveness of technologies for welfare and wellbeing;
    - Developing technologies that do not only address the economic dimension, but also the societal dimension (aesthetics – quality of the environment, sustainability, safety, involvement of individuals, etc.).
      → ensure availability of attractive options for large-scale PV use in different market segments.

Seizing the market opportunities requires an integral approach, in which research and development of world-class (competitive and innovative) technology is combined with addressing the desires and needs of individuals and society. The latter implies that the Innovation program goes beyond purely economic and technological aspects (especially since prices do not yet reflect all costs and benefits of PV technology and its competitors). This is demonstrated in the program through user dialogues, product and system demonstrations, explicit focus on sustainability, attractive design, and many more.

1.3.2 Innovation themes (Program lines)

The main Program Lines (see section 1.2.2), that are further detailed in Chapter 2, are:

1. **PV Systems & Applications (including system components);**
2. **Wafer-based Silicon PV Technologies;**
3. **Thin-film PV Technologies.**

Theme 1, PV Systems & Applications, has a clear focus on physical and electrical integration of PV. Apart from cost reduction, performance enhancement and sustainability, these are the major challenge for large-scale PV deployment.

Figure 8 gives an overview of the expected evolution of the commercially available PV technology portfolio. It clearly shows the technology pillars as well as the strategic longer term topics in Themes 2 and 3 covered in this Innovation Contract. Cost reduction, performance enhancement and sustainability are main drivers for development in these areas.

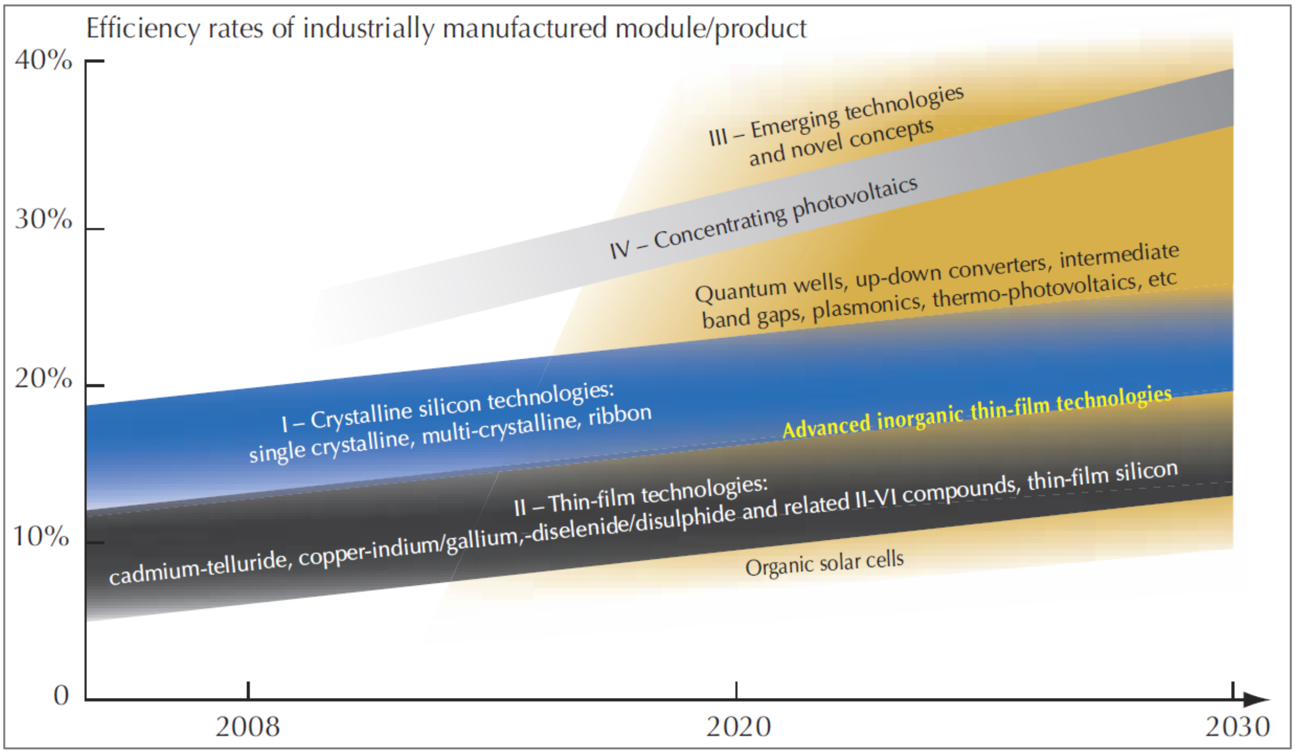

Figure 8: ***Expected evolution of the commercially available PV technology portfolio (Source: Solar Energy Perspectives, IEA, 2011)***

Note that sustainability has several dimensions, which are all addressed in this Innovation Contract: supply chain security (incl. price stability), recycling and cradle-to-cradle approaches, low (zero or positive) impact manufacturing, installation, operation and decommissioning, and public support.

Long-term agenda: where academia, research institutes and companies meet

The long-term research and innovation agenda consists of two elements:

- high-risk, high-potential developments, which can be implemented in the current themes;
- new technologies and approaches, which may potentially replace or complement existing options.

These elements are addresses as integral part of the programs and projects described in Chapter 2. Academic researchers have joined researchers from institutes and private companies around specific development challenges.

Interactions with other sectors

Theme 1 has important interfaces with the themes 'Smart Grids' and 'Energy Efficiency in the Built Environment' within the Top Sector Energy. In relation to Smart Grids, it has been agreed that the boundaries of the PV theme are the PV system including the inverter. When the inverter has additional functionality above dc/ac conversion, such as grid support, interaction with Smart Grids is essential for proper programming within the Innovation Contracts. This is formally organised through the membership of the Innovation Table Solar Energy of a representative of the TKI Smart Grids. On working level both sectors will meet and cooperate within projects with joint interest. Concerning Energy Efficiency in the Built Environment, the boundary is such that the physical components needed for application of PV within the built environment are part of the PV theme. Design and optimization of energy systems for buildings (in which PV is just one of the components) is clearly a subject for Energy Efficiency in the Built Environment. The interaction is organised in a similar way as for Smart Grids. *A concrete example of joint programming is the adoption of the Solar Energy Application Centre (SEAC, see Program Line 1) in both Innovation Contracts.* Themes 2 and 3 have clear connections with the PV Solar innovation agenda within the Top Sector HTS&M. Whereas the latter is primarily structured along the lines of the enablers: materials, processes and equipment, this Innovation Contract describes what needs to be done in relation to large-scale use of PV technology. Interactions are many and intense, since both sectors work under the same roadmap and intend to form a common solar energy community (TKI), see also the Chapter on Governance.

1.3.3 International cross-relationships in the fields of innovation and knowledge

Solar Europe Industry Initiative (SEII) and European Photovoltaic Strategic Research Agenda

The European innovation programs and deployment targets provide the main international context for the Dutch Solar PV sector. In particular, the Solar Europe Industry Initiative (SEII) is fully aligned with the ambitions of the Dutch PV sector as outlined in this Innovation Contract. In many respects, this Innovation Contract is the national mirror image of the SEII. The SEII is one of the Industry Initiatives developed in the framework of the European Strategic Energy Technology (SET) Plan and aims to develop the enablers for the European 2020 targets (a.o. 20% renewables and 20% emission reduction), while strengthening industrial competitiveness and job creation. Figure 9 shows the main pillars of the SEII as well as its context (i.e.: smart grids and the portfolio of other energy technologies). A detailed description can be found on the websites of the European Photovoltaic Industry Association EPIA and the European Photovoltaic Technology Platform[26]. The ambitions in the SEII are also in line with the recently published European Strategic Research Agenda - Edition 2011 and the corresponding Implementation European Photovoltaic Technology Platform[27].

[26] www.epia.org and www.eupvplatform.org.

[27] See Ref. 26.

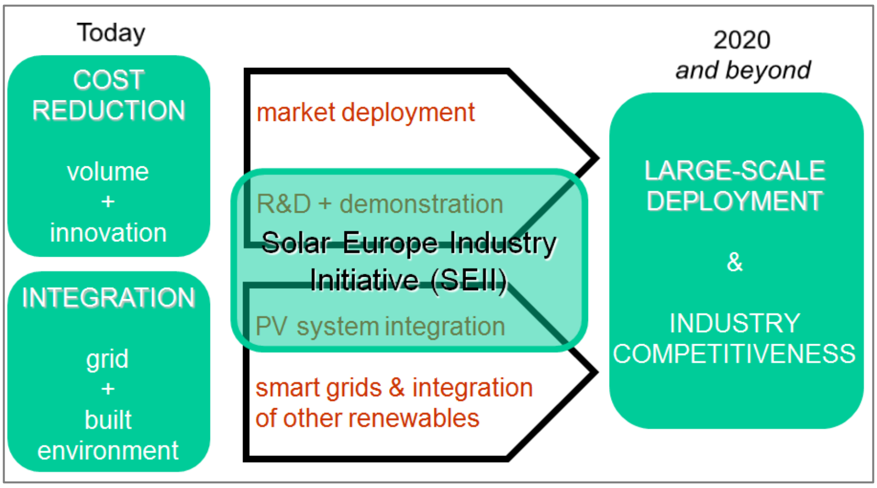

Figure 9: ***Structure and context of the Solar Europe Industry Initiative (see text).***

The ambitions in the SEII are also in line with the recently published European Strategic Research Agenda - Edition 2011 and the corresponding Implementation Plan[28]. The Netherlands has played a very active (and often leading) role in the definition and implementation of these European ambitions and plans and has a track record of leading major European PV projects.

European Energy Research Alliance (EERA)

Forming the complement of industry-driven Initiatives such as the SEII, EERA aims to strengthen cooperation between the key energy research institutes and groups in Europe. By joint programming and research, facility sharing and exchange of staff, the members of EERA contribute to enhancing the innovative power of the European energy research, of which photovoltaics is an important part. ECN is one of the active members of EERA and coordinator of its PV program.

Energy Materials Industrial Research Initiative (EMIRI)

Developed as a vehicle for the execution of the EU Materials Roadmap Enabling Low Carbon Energy Technologies[29] ("Materials for the SET Plan", December 2011), this Initiative aims to form a European PPP for strategic, industry-driven energy materials research. Photovoltaics is a prominent topic within EMIRI, which is endorsed by several Dutch parties (including ECN).

PV ERA-NET and FP7

One of the first dedicated budget lines for research under the SEII is a series of joint PV ERA-NET calls, in which a number of members states and the European Commission team up around priority areas (project clusters) for industrial innovation. These clusters are:
Cluster 1: Solar glass and encapsulation materials;
Cluster 2: Si feedstock, crystallization and wafering;
Cluster 3: High efficiency PV modules based on next generation crystalline silicon solar cells;
Cluster 4: Innovative processes for inorganic thin-film cells & modules: manufacturing demonstration;
Cluster 5: Dedicated modules for BIPV: design and manufacturing;
Cluster 6: Concentrator technology: development of components (cells, optics, trackers) and demonstration of systems;
Cluster 7: Grid integration and large-scale deployment of PV: technologies and concepts for maximum value and high penetration (including smart PV modules).

[28] See http://www.eupvplatform.org/publications/strategic-research-agenda-implementation-plan.html.
[29] See http://setis.ec.europa.eu/activities/materials-roadmap

Because of the strong position of the Dutch PV sector in most priority areas and the excellent match with the themes of this Innovation Contract it is essential for The Netherlands to participate actively in these ERA-NET calls, starting from 2012 (through a dedicated budget line from the Ministry of EA&I of typically 1 M€/year). Another source of funding for project under the SEII is the 7^{th} Framework Program of the EU (FP7), which refers to SEII targets and priorities in individual calls.

Horizon 2020

Currently the priority areas for Horizon 2020 (the follow-up of FP7) are under discussion. Several European organisations have made a strong plea to allocate a dedicated budget line for the SEII (and other initiatives in support of the SET-Plan and the EU 2020 targets). This would be a big step forward in SEII funding and would strongly support national industry-driven innovation programs such as this Innovation Contract.

Bilateral cooperation

Bilateral cooperation (beyond projects in international programs) of The Netherlands with other EU members states or regions and countries outside Europe are many. They occur as research agreements (e.g. with Imec in Flanders, RWTH-Aachen in North Rhine-Westfalia, and NREL in the USA), but also in the commercial domain (e.g. with companies in China, Taiwan and Japan). On the one hand these cooperations are an important vehicle for structural (instead of *ad hoc*) joint research; on the other hand they provide an important channel for deployment of technology and thus are a practical “proof of excellence”.

Global context

In the global context, the International Energy Agency Photovoltaic Power Systems (IEA PVPS) tasks are the key vehicles for international cooperation. They provide essential platforms for the discussion and definition of common priorities and targets and are truly “value for money”. In the area of norms and standards SEMI and CENELEC/IEC are the leading international bodies. Active participation of the Netherlands in these international tasks and working groups is important for the early influx of information on new developments and to safeguard the interests of Dutch companies in the development of international norms and standards.

In the field of deployment it is important to also mention the reformulation of the European Building Directive of 2010 on energy performance of buildings. The implementation of this Directive into national legislation will lead to a significant demand of PV and BIPV in the 2015-2020 period.

1.3.4 Human Capital Agenda

The Solar PV sector can only grow rapidly if sufficient, adequately educated and trained staff is available. As indicated in sections 1.1 and 1.2 the sector aims to grow from 2300 fte in 2010 to up to 10,000 fte in 2020. Roughly 75% of the jobs is expected to be in the upstream part of the value chain, some 25% in the downstream (installation, operation & maintenance). Table I gives an overview of the typical requirements of the sector in terms of the numbers of fte and education levels (VBO = vocational, MBO = secondary vocational, HBO = applied scientific / bachelor and WO = scientific / master)

	2010	**2020**
VBO	300	1,500
MBO	1,100	5,000
HBO	600	2,500
WO	300	1,000
Total	2,300	10,000

Table I: estimated education requirements for the growth of the Solar PV sector.

It is noted that the sector, in close cooperation with other educational institutions and associations has already taken initiative to develop dedicated programs. In particular, the following actions are on-going (list is not complete):

- Training and quality assurance for installers (UNETO-VNI / Holland Solar);
- PV / renewables programs (lectorates) at a number of universities of applied sciences – a.o. Zuyd, Saxion, NHL, InHolland;
- PV / renewables programs (master programs) at a number of universities – a.o. Utrecht, Delft, Eindhoven, Groningen, Amsterdam;
  PV program within the European Master Renewable Energy (provided by Dutch participants Hanze and NHL Universities of Applied Sciences, and ECN).

Many participants in this Innovation Contract are also involved (personally or through their organisations) in developing and providing the abovementioned trainings and courses. This is important to design the curricula such that they match immediate and future demand of the solar energy sector.

The Solar PV sector requirements are largely in line with those of the High Tech Systems & Materials sector and partially with those of the Energy Efficiency in the Built Environment and Smart Grids sectors.

A key recommendation to the Top Team Energy is to facilitate a platform (e.g. website) for exchange of up-to-date information on all initiatives in the field of training, education and certification (not just solar energy, but energy in general). There is a lack of coordination and even basic information on the multitude of such initiatives, which leads to unnecessary duplication and inefficient use of resources.

1.3.5 International policy

The Netherlands has worked together intensively and successfully for many years with research partners and companies in Germany, Belgium, Norway, France, Switzerland, Spain, United Kingdom and a few other European countries. Germany and Belgium are natural partners, as is demonstrated by the establishment of Solliance, which covers the Eindhoven-Leuven- Aachen region, but also by a recent joint DE-NL top-level seminar in Dresden on collaboration between Lower Saxony and The Netherlands in the field of PV. In addition, Germany is the leading country in the world in the field of PV technology and applications, making it an essential partner for R&D and market for commercial products. However, important bilateral relations exist with almost all important institutes in Europe, see also section 1.3.3. These have greatly helped The Netherlands to build its current position as a small country with big contributions to the field of PV.

1.3.6 Legislative and regulative framework / barriers

With prices rapidly decreasing and self-sustained markets for PV systems being formed, the main barriers for large-scale deployment of PV are related to integration of PV into the electricity grids, including the corresponding business models. For the short term, the existing system of net metering should be expanded to include other forms of PV system ownership than individual owners with a roof of their own. This would greatly enhance the possibilities for self-sustained market growth over the next 4 years. In the somewhat longer term (2016-2020 and beyond), when PV generation costs are well below retail electricity prices, net metering may be gradually replaced by a scheme based on avoided costs of purchase in combination with revenues from sales to the grid. In all cases, however, guaranteed access to the grid is essential for PV market growth (supported by technology development as part of this Innovation Contract). As the degree of penetration of PV increases, it requires new forms of regulation and an integral approach to design of the energy technology portfolio, including smart grids and storage.

The reformulation of the European Building Directive of 2010 on energy performance of buildings is important to mention. The implementation of this directive into national legislation will lead to a significant demand of PV and BIPV in the 2015-2020 period.

2 Actions

We detailed the first version of the Innovation Contract document together with the industrial partners that signed a Letter of Intent in the first round (December 2011) and other stakeholders. We defined collaborative projects in line with the vision and ambitions of the Innovation Contract Solar Energy. All project proposals include at least 40% private contributions committed by the industrial partners with Letters of Commitments, signed by responsible officials. All projects lead to concrete short term actions for the Innovation Contract Solar Energy.

For PV to fulfil its promise as major renewable electricity source within the coming 50 years, and for the Dutch PV sector and society to take full benefit from the spectacular growth expected, several steps need to be taken and existing initiatives need to be continued:

- Continuous incorporation of new products and concepts into the Dutch PV sector to assure that it can deliver ever cheaper PV products with higher electrical output levels and with an ever improving environmental profile and user attractiveness as prerequisites.
- Enabling and supporting this innovation process by developing the required enabling technologies making use, and extending, the renowned knowledge position in PV of the Dutch industrial companies as well as the Dutch research institutes. This process will be crucial to secure and extend the excellent position of the Dutch PV manufacturing equipment industry, as well as other PV industry sectors.
- Facilitating the transition process from centralized electricity production mainly based on fossil fuels into an energy system that makes full use of sustainable, mainly decentralized electricity production with PV as an important part of the energy mix. This transition will ask for physical integration (into the built environment and the infrastructure) as well as electrical integration (into the grid), but also informing and involving the end-users (the Dutch society) in development and deployment of PV.

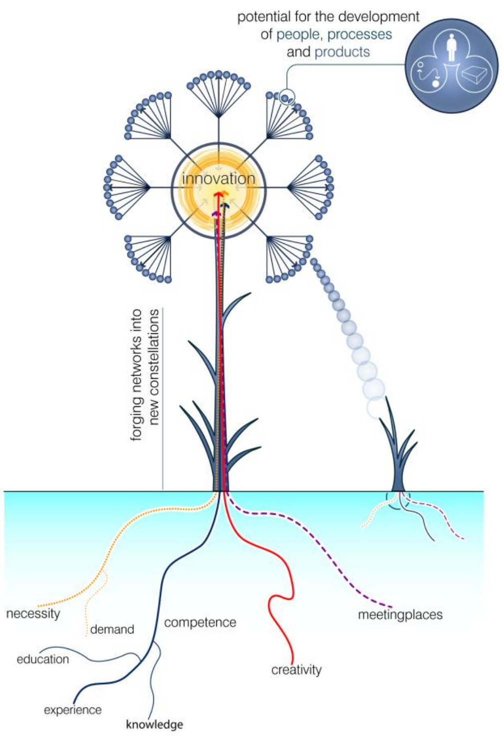

Figure 10: Spreading innovation through novel networks

- Enabling and supporting this innovation process by developing the required enabling technologies making use, and extending, the renowned knowledge position in PV of the Dutch industrial companies as well as the Dutch research institutes. This process will be crucial to secure and extend the excellent position of the Dutch PV manufacturing equipment industry, as well as other PV industry sectors.

For the Dutch PV sector it is of utmost importance to have an excellent R&D infrastructure that enables intense contact and interaction between suppliers, clients and R&D institutes. Proposed programmes and instruments will create such infrastructure in terms of centralised facilities as well as integrated research and innovation plans. Hence, it will stimulate companies and people to collaborate in novel constellations: people with diverse competence and common interests in new networks and meeting places, where new ideas can develop into profitable solutions. While the “right” constellation is a subjective term (as it highly depends on the characteristic of each problem and the availability of competence and creativity in given networks) it is considered absolutely necessary to facilitate arenas focusing on breakthrough and continuous innovations. The ambition for the Innovation Contract Solar Energy is to bring together different constellations of people and tools, hence forging competence and creativity into innovative rewards for industries and society, that may come in the form of new or renewed materials, processes, solar electricity products or better educated and inspired people.

Figure 11 illustrates the fields of action of the Dutch PV sector and the Innovation themes within this Contract. The two pillars (Wafer-based Silicon and Thin-film PV Technologies) represent the heart of any PV system. Companies and research institutes active in these fields work in the underlying areas Materials & Processes, Equipment & Manufacturing Technologies, Cells & Modules (i.e. devices), as well as, for instance semifabricates for building integration. These two pillars support the actions and ambitions in the field of PV Systems & Applications, where the Industry Vision and Deployment Vision meet. The interactions between the two main fields of action are shown in the right part of the figure.

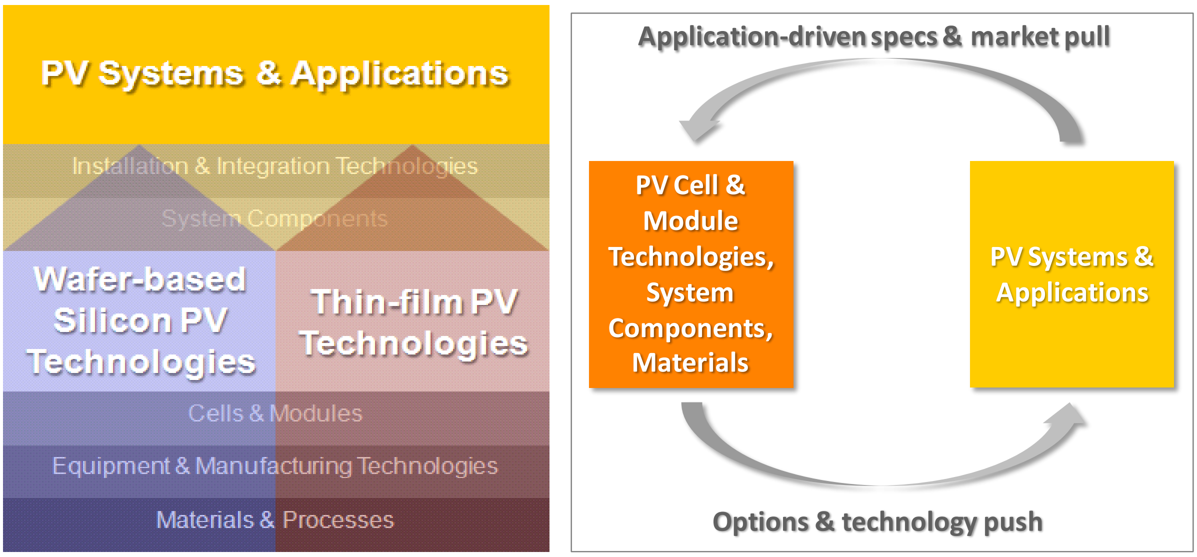

Figure 11 and Figure 12: Innovation themes (left) and their interactions (right).

In the following sections the corresponding Program Lines are detailed and motivated:

1. PV Systems & Applications;
2. Wafer-based Silicon PV Technologies;
3. Thin-film PV Technologies.

Projects reflecting industry priorities are the building blocks for each Line. Since submission of the first version of this Innovation Contract in December 2011, each Program Line has been elaborated further and concrete project proposals have been prepared as initial actions under the Innovation Contract. Each project answers to specific targets and aims of this Contract, supports the overall goals, and transcends individual industry partners' interest. Projects are summarized within the main text of this Contract while the more detailed descriptions are added as (as yet confidential) appendices, together with the Letters of Commitment from industry partners.

2.1 Program Line PV Systems & Application

In 2011, the contribution of PV to the electricity supply was still rather small in all parts of the world, with the exception of Germany, where it reached 3%. This situation is expected to change rapidly as PV soon reaches grid parity on various price levels in the coming decade and self-sustained markets will form.

The Netherlands was one of the first countries to demonstrate a large number of PV systems fully integrated into a newly built zero-emission urban area (City of the Sun, Municipality of Heerhugowaard, >5 MWp in total). This and other projects have yielded valuable and unique experience about integration of PV into building elements and the integration of PV into the electricity grid. These factors place The Netherlands in an excellent position to develop and deploy innovative PV systems in large volumes over the coming decade and in the longer term.

This part of the supply chain (systems, building integration products, grid integration products) is regarded predominantly as local-for-local business. The reasons that we expect this business to remain local-for-local (and not globalize), are:

- aspects of regulations: building codes, regulations and laws on the built environment, grid integration and energy supply;
- aspects of culture: aesthetics of the built environment, culture and way of working in the architectural and construction business segments;
- aspects of supply chain: product diversification on BOS elements, architectural building blocks and system components is large, the number of companies involved in this part of the business is >1000 (as opposed to much smaller numbers of companies in cell and module manufacturing), relatively high cost of shipping high mix/ low volume/ high weight components and systems.

Whereas PV technology R&D is primarily focused on economic activities in the field of PV producers, equipment manufacturers and specialty materials suppliers, the RD&D activities in the Program Line PV Systems & Applications are primarily focused on economic activities in the downstream part of the solar energy value chain: system suppliers, installers, BIPV suppliers, grid integration product suppliers, architects, roofers, construction companies, etc. This Program Line will contribute directly to the target of 4 GWp installed capacity in The Netherlands in 2020 and to:

- the 2020 targets of CO_2 emission reduction;
- a strong growth of economic activity in the field of solar energy systems and applications.

The Program Line PV Systems & Applications is part of two Innovation Contracts under the Top Sector Energy: “Solar Energy” and “Energy Efficiency in the Built Environment”. The proposed executing organization for this Program Line is the Solar Energy Application Center (SEAC) which is also a key pillar of the TKI ‘Energy Efficiency in the Built Environment’ and has, in addition, a bridge function towards the TKI Smart Grids. Participants in the SEAC are a.o. ECN and TNO.

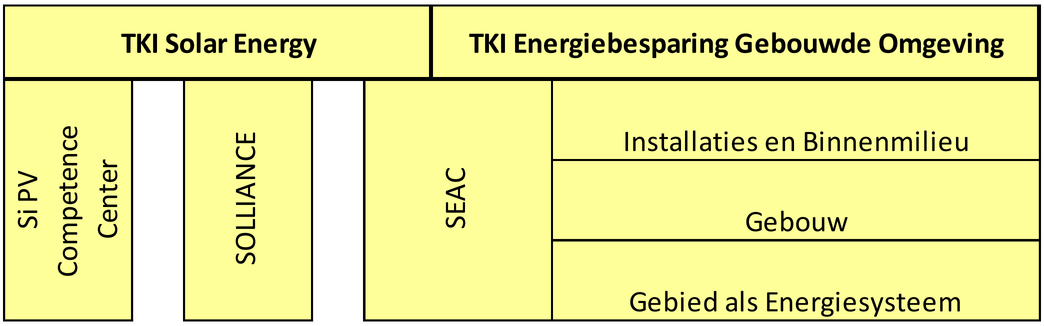

Figure 13: ***Relation between the SEAC and two of the TKIs within the Top Sector Energy.***

SEAC is an *alliance* for research, development & demonstration (RD&D) of applications of solar energy systems, in the built environment, infrastructure and networks, including their mechanical and electrical integration. The purpose of this alliance is to strengthen the connection of the research and development activities with economic activities in The Netherlands and in the ELAt region. The field of activity of SEAC is largely complementary with Building Integrated High Tech Systems (BIHTS), a recent regional initiative of private and public partners in the (cross-border) region of Limburg. Current partners in BIHTS are Municipality of Heerlen, City Region Parkstad Limburg, Zuyd University of Applied Sciences/CoE Neber and the Province of Limburg and a renowned test and certification company. It is the explicit intention of all partners involved to establish a cooperation between SEAC and BIHTS in order to form a strong player in the field of (o.a.) solar energy systems and applications. Concrete discussions have started shortly before the deadline of this Contract. Although regional in its starting position, cooperation will be sought with other parties in The Netherlands and surrounding regions, to create synergies and critical mass in this important field of operation. SEAC aims to be the primary point of contact for industrial partners and for new business initiatives towards the experts community. BIHTS seeks to strengthen the regional economy.
In the following, details are given on the ambitions and program of SEAC as formulated thus far. Brief information on BIHTS can be found in the attached project description. Information on the cooperation between SEAC and BIHTS will be made available after discussions following the recent signing of an MoU between partners.

The *ambitions* of SEAC:

- Develop hardware an installation approaches for physical integration of PV in the built environment and the infrastructure. This is essential for large-scale deployment in densely populated countries such as The Netherlands and provides major export opportunities to other countries, especially in Europe.
- Develop hardware and concepts for integration of PV into the electricity grids at high levels of penetration, maximizing the value of PV electricity and optimizing the output of PV under the complex conditions that prevail in the built environment.
- A highly service-oriented laboratory infrastructure for development, testing and demonstration of solar energy system applications and system components, aimed at Development and Deployment, that is being used by the majority of companies in the relevant parts of the value chain.

Main *activities* of SEAC in these fields are the development of new concepts, techno-financial calculation models, benchmarking, design, prototyping, pilots and 'proeftuinen' and prequalification.

2.1.1 Sub-programs

"PV Systems & Applications" covers the part of the solar energy supply chain starting at, and downstream from the solar module or collector. We define two sub-programs in this Program Line: Physical Integration and Electrical Integration.

1. **Physical integration**: building blocks, prefab systems and other dedicated products and design concepts for integration of solar energy systems in the built environment and the infrastructure;
2. **Electrical integration**: electronic devices and system design approaches that enable a high penetration of PV systems in the grid and maximize the value of the electricity generated.

These sub-programs are further divided into technology themes, see below.

2.1.2 Technology Themes

2.1.2.1 Physical integration

<u>Building Integrated Photovoltaics</u>

The application of Photovoltaic technology transforms buildings from energy users to energy producers. In addition to the older concept of PV installation or "building applied photovoltaics (BAPV)", a new technology is emerging: Building Integrated PV (BIPV). This refers to a merging of the construction technology with PV: the architectural, structural and aesthetic integration of PV into buildings. In the BIPV approach, the PV modules become true construction elements such as roofs, façade or skylight elements. We therefore define BIPV components as PV components that are designed to serve as part of the building envelope and have - in addition to the function of energy generation - one or more of the following functionalities: weather protection, thermal insulation, noise protection, modulation of daylight and aesthetic value.

The adoption of PV *in the building process* (in renovation programs and new-built projects) will depend on the availability of the right product portfolio of BIPV building blocks and complimentary electronics devices for integration into buildings, infrastructure and networks. A new generation of related solar energy products will be developed within this Innovation Theme. This means that apart from standard PV characteristics to be considered like electricity production (kWh/yr), investment cost (€) and maintenance cost (€/yr) also other characteristics need to be considered like color, appearance, size, weather tightness, safety in the construction, mechanical connectivity and electrical connectivity.

The main technical challenges for BIPV are:

- BIPV products have to perform as building material. This means: functionality as part of the building envelope (weatherproofing, thermal insulation, noise insulation, etcetera), but also a durability equivalent to the materials replaced. Some EU building codes also forbid the use of EVA as encapsulant.
- Reasonable access to replacement, repair and maintenance.
- Aesthetics and full flexibility in color, shape and size against reasonable cost.
- Ease of installation. This means that the electrical connection system is designed “plug and play” (even wireless is an option). Mounting systems in line with construction practice.
- Efficiency. Efficiency is the main driver for kWh/m^2 energy generation.
- Low cost.
- Prevention of BIPV module heat-up. For instance using back ventilation.
- Low weight. Maximum weight load of many existing roofs is too low for standard solar installations. In addition also for installation of façade systems, the weight of the modules translates into a cost factor.
- System design to prevent power loss from shading and pollution. One option is the development of micro-inverters (see Project 7).
- Product design to minimize power loss for non-optimum orientations, e.g. in facades.
- BIPV on non-glass materials.

Figure 14 and Figure 15: ***Solar tiles and shingles.***

Figure 16 and Figure 17*: Semi-transparent façade based on crystalline silicon- and thin film- technology.*

Figure 18 and Figure 19: *A façade cladding PV solution and thin film PV solution on a curved roof.*

Prefab Solar Roofs

Prefab solar roofs are complete roof-solutions with integrated solar energy functionality (PV and/or solar thermal). Application of prefab solar roofs means that no on-site module installation is needed. Apart from generation of solar energy, prefab solar roofs may have the purpose of protection against water and thermal insulation. Application of prefab solar roofs has the following benefits:

- Creation of the prefab roof takes place off-site on an assembly site, where the work can be planned independently from weather conditions.
- Reduction of installation time.
- Enhanced quality of the installation work.
- Avoid cost due to safety aspects of time-consuming panel-for-panel mounting on a roof.
- Cost advantage with respect to on-site panel mounting.

Some initial experiments with prefab PV roofs have been carried out, for instance the prefab PV experiment in the ‘Stad van de Zon’ in Heerhugowaard. The promise of this approach for cost effectiveness and standardized flexibility is apparent. However, many challenges still need to be overcome.


Figure 20 and Figure 21: ***Prefab Solar roofs***

Integration of PV into Infrastructure
This topic concerns the challenges that are faced when integrating PV into dikes, sound barriers, roads and ground based projects. This relates to optimizing the carrier constructions, project layout, electrical line diagram and safety aspects.

Technical challenges on this topic are:
- System configuration for elongated configurations along roads and dikes: how to optimize cabling and inverter string layout;
- connection to the grid: due to location of the systems and the expected large size separate grid connections need to be made. How to optimize in view of cost and exploitation;
- safety; in for instance sound barriers; module integrity, behavior under calamities, access and flight routes;
- life span and durability; infrastructure objects are expected to have a long life span with minimum maintenance, whereas the environment in most cases poses extra load due to chemical substances (salt), abrasive particles (steel and stone grit). Moreover, the locations are in general more exposed to the elements.


Figure 22 and Figure 23: ***PV on a sound barrier and in a horticultural application.***

Horticulture Greenhouse Solar Systems
In horticulture greenhouses, the challenge is to optimize temperature, light and CO_2 concentration for each specific crop against the lowest possible energy cost. PV and can play a role in that, if combined in a smart way into a total system approach.

Sunlight is the driving motor for the growth of crops in a greenhouse. Especially for vegetable crops, the more sunlight, the better production. Typically a combination of red and blue light is sufficient for optimum growth. Details depend on the type of crop. Also the optimum light *level* depends on the crop. Some crops (e.g. pot plants) are shade tolerant, others need as much light as possible (with avoidance of burning damage by direct sunlight). Many crops also benefit from an elevated CO_2 level in a greenhouse. In order to keep the CO_2 level elevated, the greenhouse needs to be closed. Typically in winter the temperature is lower than optimum, while in summer the temperature tends to get too high. In a straightforward solution the greenhouse is heated in winter and cooled in summer for instance by opening windows, which makes it difficult to keep an elevated CO_2 level. Another strategy is the use of thermal screens in summer. In practice greenhouse farmers chalk out part of the glass surface depending on season.

In a (semi)closed greenhouse, the excess energy available in summer is stored as heat and used in winter. One way is to use coolers in summer and store the energy in 100m deep aquifers at approximately 18-20^{o}C. Another way is to use movable PV shields that cover the south oriented roof parts of the greenhouse as soon as a threshold level of light and temperature is reached. However light for PV competes with light for the growth of the crops. Potential directions for a solution are to use the system only for shade tolerant crops, to use the generated electricity for generating only the needed wavelength of light (using LEDs) or to use some way of spectral separation.

Dutch companies, like Van der Valk, Alkupro, Elkas developed concepts based on integration of PV in the greenhouse. In general these are semitransparent systems where a fixed part of the greenhouse roof area is used for PV. The immediate problem of these systems is that this area is fixed and cannot be varied depending on season, weather or crop type. Van der Valk systems posed the idea of flexible sunshades with integrated PV. The problem with such systems is that the kWh yield of the PV is limited, making it hard to justify the investment.

Elkas (WUR) proposed to separate the near-infrared (NIR) part of the spectrum from the sunlight using a reflective foil and use this part of the spectrum for PV. Another idea of the WUR is to separate direct sunlight from diffuse sunlight using a Fresnel lens, and use the direct light for PV and the diffuse light for growth of the crop.

A theoretically ideal system for a greenhouse application would be a spectrum selective PV system that uses the green and NIR light for PV and leaves the blue and red part of the spectrum for the growth of the crop. Technical issues and challenges:

- For any of the above indicated systems, the challenge is to obtain low cost and high efficiency;
- How to combine flexibility depending on crop, season and weather with PV efficiency, kWh yield and acceptable ROI;
- Develop spectrally selective PV systems or other efficient means of spectrum separation;
- To prove that introducing smart PV systems does at least not negatively influence the growth of the crop.

<u>Solar Thermal and integrated PV-Thermal Systems</u>
Solar Thermal Energy is the direct creation of heat (hot water, hot air) from solar energy. Since transport of heat is more expensive compared to transport of electricity, storage of thermal energy is a logical aspect to be included in the design of solar thermal systems. Storage of thermal energy in a building is an essential aspect for the "CV-loze woning". PV-Thermal systems are combination systems designed to harvest solar electricity and solar heat in such a way that the total harvested energy per m^2 is larger than for either solar thermal or PV.

Solar thermal systems are widely available and have reached a mature stage with respect to development. Absorbers in collectors have reached high efficiency levels, control units and storage tanks and heat exchangers leave little room for improvement. However, using the sun as a reliable and continuously available source of thermal energy requires more research on for instance storage systems.

The combination of solar thermal and PV at first sight appears to be a logical step to increase overall efficiency. However currently available systems do not reach the yield levels of separate systems, and have a relatively high cost level. Companies like Unidek and Redenko have built up some initial experience with PVT integration for roofs.

2.1.2.2 Electrical integration

Electronic Systems and Components

PV systems can be implemented in a range of applications, sizes and situations, meeting a large range of power needs. For a high penetration of PV, electronic system components (inverters, storage devices, control components) need to have long lifetime, reliability and low cost.

Lifetime and reliability of inverters are typically lower than those of the PV modules. This is one of the bottlenecks for market penetration of PV and BIPV especially, since maintenance work on many small systems in the built environment should be minimized.

Performance of systems need to be optimized under various circumstances. One example is the performance optimization under partial shadowing or contamination. Such a system needs specific components developed with the optimized system in mind. Other examples of performance optimization are remote monitoring and service systems and, automatic cleaning systems. This type of systems need specifically developed components.

In summary the technological issues for electronic system components are:

- Electronic system components with high efficiency, low loss and increased component lifetime (20 yrs);
- Micro-inverters for performance optimization of BIPV;
- Storage devices for storing electricity for various timeframes;
- Cost-effective components for remote performance monitoring of large numbers of distributed PV systems;
- Components that enable system performance optimization;
- Installation and maintenance issues (install, service, replacement).

Control systems and Grid integration

The National Action Plan Solar Electricity (see ref. 11) The Netherlands foresees in 4 GWp installed in 2020. Although this corresponds to a modest percentage of generated solar electricity with respect to total demand, in terms of peak load on sunny days it represents a considerable penetration. As the total installed capacity of sustainable electricity generation from wind and solar PV increases, kWh supply and price/kWh will vary over the day and from day to day. This implies the need for supply and demand systems. On a small (user) scale: optimize the kWh usage and cost. On a larger (network and utility) scale: systems for forecasting, planning and price setting, systems to actively manage local storage and trading, systems to control the power quality on the grid. Furthermore, a larger PV electricity supplier who operates a portfolio of smaller PV systems will strive to optimize the design of the portfolio of systems in terms of connection locations to the grid and in terms of orientation of individual systems for optimizing generation over the course of the day. Many of the examples above refer to ways to maximize the value of the generated electricity. In summary the technological issues for grid integration and control are:

- User demand management systems that optimize local consumption of the electricity at the point of generation in order to minimize cost for the user;
- Grid supply and demand management systems in order to reduce grid loads. This includes forecasting;
- Management systems for electricity trading, storage and power quality control;
- System portfolio optimization systems.

2.1.3 Projects

The subprogram **Physical Integration** focuses on defining and executing projects in cooperation with industrial partner(s). The overall goal of the program is to create systems and components that fit market requirements. The projects focus on developing, demonstrating and prequalifying new products that offer an improvement on at least one of the key market challenges and/or technical challenges as outlined above. A key project is the creation of a 'BIPV proeftuin': a building on which new BIPV systems of various suppliers will be installed, demonstrated and monitored. SEAC develops and maintains techno-financial models. These models include investment cost for different BIPV solutions, kWh yield and ROI calculation.

Based on priorities and plans expressed by companies, the following projects have been defined. For the project descriptions, see Appendix.

1. BIPV
2. Prefab Solar Energy Roof
3. EnergyWall
4. Greenhouse PV
5. Applications of Flexible PV

The subprogram **Electrical Integration** focuses on the following topics:

- development of yield optimization systems;
- research on installation and maintenance issues; failure detection and identification;
- service/maintenance methodology;
- monitoring and measurement (smart meters);
- user demand management systems;
- demand management system hard-& software development;
- user interfacing and user acceptance;
- grid connection principles in relation to the various regulations in different countries.

The SEAC proeftuin will set-up a pilot for two concepts of performance optimization of PV Systems (see Project 6). We defined together with companies, the following projects. For the project descriptions, we refer to the Appendix.

6. Module Level Power Management;
7. Smart Modules;
8. Virtual PV Plant with Storage Integration;
9. Solar Monitoring / PV-BOX.

BIHTS (see text) is added as a separate project, to be linked to SEAC in a later stage.

2.1.4 Instruments

The Program Line "Solar Energy Systems and Applications" and the executing organization SEAC have been jointly adopted by the Innovation Contract "Solar Energy" and the Innovation Contract "Energy Efficiency in the Built Environment". There is a substantial level of company commitments for this Program Line.

In addition there is a written intention for regional co-financing for the SEAC for an amount of approximately 1.3 M€. The University of Utrecht and the TU Delft propose to finance their contribution to the Program Line via NWO. We propose to finance the remaining part for this Program Line via "Innovatie uit SDE".

Note 1: in the table below the very recent BIHTS initiative has not yet been financially integrated

Note 2: private and public funding are shared between the Innovation Contracts Solar Energy and Energy Efficiency in the Built Environment.

Program line Systems and Applications	Project duration start (yr)	end (yr)	Participating industrial organisations	Private funding	Public funding
TOTALS				22.473	33.710
Physical integration	2012	2016	Oskomera, Dimark, Eternal Sun, Peerplus, Bouwend Nederland, Chematronics, KIWA, Rimas, Rollecate, Scheuten Solar, SED, SunCycle, Trespa, Tulipps, Voest Alpine, Xyztec, Yparex, Energiedak, Ballast Nedam, BDA, BOAL, Unidek, Itho, Van Campen, Green Campus, …	9.925	14.888
Electrical integration	2012	2016	Femtogrid, Heliox, Alrack, Alliander, Mastervolt, Scheuten Solar, SMN, Sunweb Solar, Sioux, Proxenergy, Smart Cities, KEMA, …	12.548	18.822

2.2 Program Line Wafer-based silicon PV Technology

The Dutch high tech industry has an excellent position in wafer-based crystalline silicon with leading suppliers like Tempress, OTB, and Eurotron. Also, DSM , Meco, and ASMI are upcoming players with products in the market. New players are SoLayTec and Levitech, the result of long term investments in Dutch academia and in Eindhoven University of Technology, specifically. The main deliverables of this Program Line are technology packages of new products that contain patent protected technology in the form of concepts and processes, and related equipment and materials that can be delivered by Dutch companies .

Success of this subprogram is qualified similar to the success of Tempress and ECN with the PANDA module, that is in mass production by world's number 3 PV-manufacturer Yingli Green Energy. However, the aim is to broaden the benefits to include other Dutch companies. Basically, the success of one Dutch company should lead to the success of the others as well. The mechanism to achieve this is to have ECN and the other knowledge institutes deliver patented technology packages that include as much Dutch technology as possible.

What does this mean for economic benefit to the Netherlands? In the below figure, the revenues of Amtech, mother company of Tempress are depicted. This revenue is mainly determined by Tempress, the sole contributor to solar revenues of Amtech.

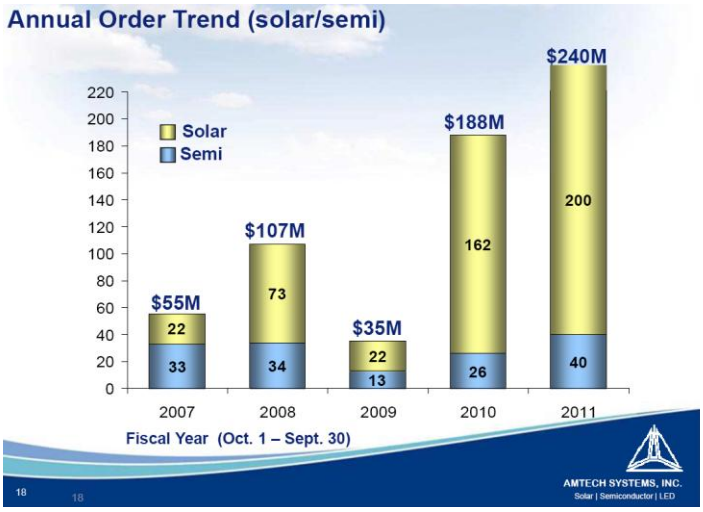

Figure 24: ***Amtech revenues***

Amtech entered the Solar energy business in 2005, starting with the collaboration with ECN. Success of this Solar Innovation Contract approach will lead to a similar expansion for Tempress as well as other Dutch suppliers. Assuming a similar growth path for all companies involved (7 currently), this program line of the Innovation Contract Solar alone will lead to revenues in 2015 between 2000-5000 M€ (and 5000-10000 high tech employees and between 50-200 Meuro in tax revenues). A positive return on investment within a period shorter than the length of this Innovation Contract is foreseen.

2.2.1 Sub-programs

This Program Line is focussed on the main product on the market: crystalline silicon based PV modules, with 80% market share at the moment. Experts foresee that this technology will remain leading during the next decade. The Program Line is divided into two Subprograms for development of:

1. High-performance PV modules;
2. Enabling industrial manufacturing technologies for high-performance PV modules

2.2.1.1 High-performance PV modules.

A recurrent theme for development in PV technology is always the demonstration of solar cells and modules with good cost-performance ratio. Therefore, the two-year aim of this subprogram is to demonstrate a world-class 20% efficient modules at total production costs of 0.6 euro/Wp with Dutch equipment, materials and intellectual property. The five-year aim is the demonstration of 22% efficient modules at predicted production costs below 0.6 euro/Wp with nanotechnology patented and developed by Dutch academia.

The products that are worked on are the following:

1. High power n-type modules, based on the product marketed by Tempress and ECN and on the market by Yingli (at annual turnover 500 M€). Innovations should lead to low cost metallisation, 10% higher power output, and 5% lower costs. New equipment should include plating by Meco (part of Besi, Drunen), PVD and inkjet from OTB Solar, ALD by Levitech, Solaytec, and/or ASMI. New materials should come from DSM (encapsulants) and Cookson, Enthone (‘s Hertogenbosch).
2. High power back contact modules, based on the product marketed by Eurotron and ECN. Innovations should lead to improved recycling by using thermoplastic encapsulants developed by DSM and reduced costs by reducing the amount of materials.
3. Next-generation back contact modules based on interdigitated back contact solar cells. The main innovations are in new cell designs patented already by ECN and the integrated approach using new equipment of Tempress (ion implantation) and ASM (epitaxial growth).
4. Next-generation multi-junction modules based on high efficiency approaches with nanomaterials and non-silicon based materials for concentrators. The main innovations are the integrated approach of cells and modules, implementation of nanostructures developed and patented by FOM-AMOLF, TU Eindhoven, and TU Delft.

2.2.1.2 Enabling industrial manufacturing technologies

Equipment manufacturers need to demonstrate and qualify their equipment and materials for production. Therefore, the two-year aim of this subprogram is to improve and demonstrate the applicability of current Dutch equipment for state of the art PV manufacturing. The five-year aim is to demonstrate new equipment for upcoming PV manufacturing. In this subprogram, the Silicon Competence Centre will be built up with all knowledge partners and equipment manufacturers to make a fully operational showcase of advanced Dutch equipment.
The sub-programme is built up out of several components:

1. Improved manufacturing equipment for PV. Optimisation for throughput, yield and lower investments is a main topic. Also, modifications to equipment to accommodate new wafer material is included.
2. Benchmarking equipment and materials on state of the art PV production. The Dutch equipment will be demonstrated to be better suited than not Dutch equipment for state of the art production.
3. Piloting next-generation high-performance modules. The products developed in the subprogram High-performance PV modules will be demonstrated on a larger scale.
4. Eco-monitoring and automation: Environmentally friendly production is important for large-scale production of solar modules. ECN has a track record in environmental analysis and this can be used to build an eco-monitoring of newly developed production processes. This can be built in into the Silicon Competence Centre since new lab infrastructure will be built according the zero-emissions standard. This infrastructure is the “proeftuin” for Dutch innovations in recycling, waste water treatment and abatement.

2.2.2 Technology themes

The technology themes are the specific manufacturing steps that are necessary for producing a solar module. These individual manufacturing technologies are cutting edge as is evident from the=strong position of the Netherlands' as suppliers to the PV-industry. They also are the needed to achieve ambitious efficiency and cost-reducing targets in industry, Therefore, investment through this public-private partnership (PPP) solar in these technology themes is essential in building on our excellent starting position as leading suppliers. The main idea behind this PPP is to combine the prime position in manufacturing with the excellent integration skills of the knowledge institutes to provide solutions for state-of-the-art solar modules and for next generation top-of-the-bill solar modules.

The technology themes that we use throughout this Program Line are:

- Light management and passivation technology: DSM, OTB, Tempress, ASM, Levitech and SoLayTec;
- Junction formation technologies: Tempress and ASM;
- Metallization technologies: Rena, Meco, OTB, and Enthone;
- Interconnection and encapsulation: Solland, Sabic, Rimas, DSM, Eurotron.

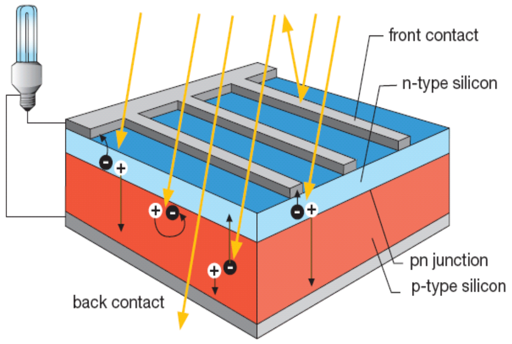

Figure 25: ***Schematic of standard solar cell***

Actions within this Program Line are directed towards compatibility of process steps and demonstrations according to the innovative targets, to give the industry, single or as a consortium, the opportunity to penetrate the market with novel technology.

2.2.3 Actions: proposed projects for 2012-2013.

Within the two sub-programmes, projects will be defined to achieve the targets. These projects will be focussed on the technology themes compliant with Dutch suppliers to the PV industry and on the integration of these themes in state of the art and next generation top of the bill high power solar modules. The combination of technology breakthroughs and novel high power module concepts is the instrument towards unique selling points for the Dutch PV industry, ensuring a good return of investment on the public investments in this innovation contract. For 2012-2013, the following projects are defined:

Sub-programme High-performance PV modules:

1. **Next generation n-pasha modules**. The aim of this project is to increase the marketability of n-pasha, a product sold by Tempress. It is based on PANDA technology being produced by Yingli, number 3 in the world. Currently, the product needs an upgrade to increase efficiency above 20% and reduce production costs. This project also aims to include more Dutch technology, in the form of materials, like encapsulant materials and equipment like plating equipment.
2. **Eco PV modules**. The aim of this project is to increase the eco-friendliness of the Eurotron product, the back-contact module production equipment. This will be accomplished by including new encapsulant materials, silver free metallisation and increasing the diversity of products that can be made by the Eurotron lines. At the same time, this project aims to include more Dutch materials and equipment and reduce production costs to make the back-contact module production line more attractive.
3. **High power modules based on interdigitated back contact cells**. The aim of this project is to provide the industrial partners with a platform to test their equipment for high-end modules with 10-20% higher power output. This means that new concepts based on patents of ECN will be developed to a next phase. At the same time, reference processing for high efficiency cells will be started based on Dutch equipment.
4. **TOP products**: This project aims to achieve the highest efficiency based on crystalline silicon. The five year vision is to go to 25% module efficiency including nanotechnology developed at TUE, TUD, and Amolf. As a next aim, production equipment will be designed to produce such a TOP module.

5. **Fundamentals**: This project is aimed at the transfer from fundamental knowledge of thin layers as being developed by academia towards the industry and work on the implementation in all of the cell concepts discussed above.

Sub-programme Enabling Industrial manufacturing technologies:

1. **Silicon Competence Centre**. The aim of this Centre is to provide a fully operational showcase of advanced Dutch technology towards the worldwide PV industry and through this showcase provide enhanced sales for the private partners. This is accomplished by investments in equipment and facilities and the establishment of reference manufacturing of full high power solar modules. The reference manufacturing is needed since commercial PV cell and module manufacturing is not present in the Netherlands. Pilot manufacturing is needed for the suppliers to show that their products work, but it is also of extreme importance to start-up companies like Alinement and TSC to have a starting point for innovative production of niche products.

2.2.4 Instruments

The industry partners involved in wafer-based silicon PV in the Netherlands have specified and quantified their research efforts in the framework of this Program Line for the next years, both in R&D-topics and in monetary value. The contribution in this table is the accumulated amount for in-house R&D and in- kind contributions to the Subprograms and actions.

Program line Wafer-based silicon PV technologies	Participating industrial organisations	Committed industry participation investm. (k€)	hours (k€)	other (k€	in cash (k€)
TOTALS		12.185	30.120	6.375	5.556
Enabling industrial manufacturing technologies	Tempress, ASM, Meco, Levitech, OTB, Eurotron, Solaytec, Sunlab	9.630	1.410	50	250
High performance PV modules	Tempress, Levitech, OTB, MECO, TSC, ASM, Solaytec, Siemens, DSM, Alinement, Eurotron, OM&T, Lamers, ...	2.555	10.060	2.050	4.916
cSi projecten 2014-2016	Tempress, Levitech, OTB, MECO, TSC, ASM, Solaytec, Siemens, DSM, Alinement, Eurotron, OM&T, Lamers, ...	0	18.650	4.275	390

Program line Wafer-based silicon PV technologies	Participating research institutes	Institutes participation EZS (k€)	NWO (k€)	EOS-PiD (k€)	IC PV (k€)	EU (k€)	Total project budget (k€)
TOTALS		14.360	23.550	321	26.060	544	119.071
Enabling industrial manufacturing technologies	ECN, Amolf, TU Delft	440	21.000	0	13.560	0	46.340
High performance PV modules	TU Delft, ECN, Amolf, TU Eindhoven,	7.020	2.550	321	4.500	544	34.516
cSi projecten 2014-2016	TU Delft, ECN, Amolf, TU Eindhoven,	6.900	0	0	8.000	0	38.215

2.3 Program line Thin-film PV technologies

The Dutch high tech industry has a strong position on the world market of thin film PV technologies with regard to the equipment for producing PV cells. Smit Ovens is world leader with regard to the thermal step in producing thin films. Also companies like VDL-ETG, Scheuten Solar, MECO, DSM and many other (smaller) companies are involved in research and development on equipment for or application of thin film technologies.

Figure 26: ***Flexible thin-film PV module.***

Although the bulk market, characterised by low cost in mass manufacturing, is of great importance, thin film technology also has opportunities in niche markets, in which cell types such as Organic PV can develop. Inherent advantages of thin film cells are: potential transparency, low weight and freedom of form. This creates possibilities for generating solar energy on (flat) roofs with little load bearing power or on roof tiles, and for the combination of PV with many different common objects, even for garments. Transparent thin PV film could also be sandwiched between double-glazing windowpanes. Europe has great opportunities. High-end manufacturing is commercially viable here, provided that innovations are applied. There is definitely a competitive edge to the development of new manufacturing processes and the application of new materials if there is also a domestic market for them. The market is very differentiated and smart anticipation is the key here, even in a world in which the competition will increase enormously. In further market development, the emphasis will shift to integrated systems, such as 'building integrated' (BIPV). But because thin film PV can be combined with so many more applications, it is better to talk about 'intelligent application', with multiple use of space as a guideline, for example cars and noise barriers. The development of such intelligent applications requires knowledge of technology as well as knowledge of law, environmental planning and financing.

ECN, TNO, TU/e, Holst Centre and the industry have bundled their activities and strengths in the field of thin film PV in the Netherlands in Solliance. With the partnership of imec a strong cross border cooperation is established with the institutes and companies in Flanders. Solliance has developed in short time to a unique co-operation network in which organisations' programs are aligned and synergies are successfully exploited. Currently Solliance is receiving requests from other knowledge institutes to join the alliance and thus Solliance is strengthening its position as a broad thin-film PV knowledge centre over the whole value chain for the Dutch Industry; ready to operate in the growing market share of thin-film PV as indicated in the figure below coloured blocks refer to Solliance focus technologies (note that organic PV is combined with concentrator PV in this figure).

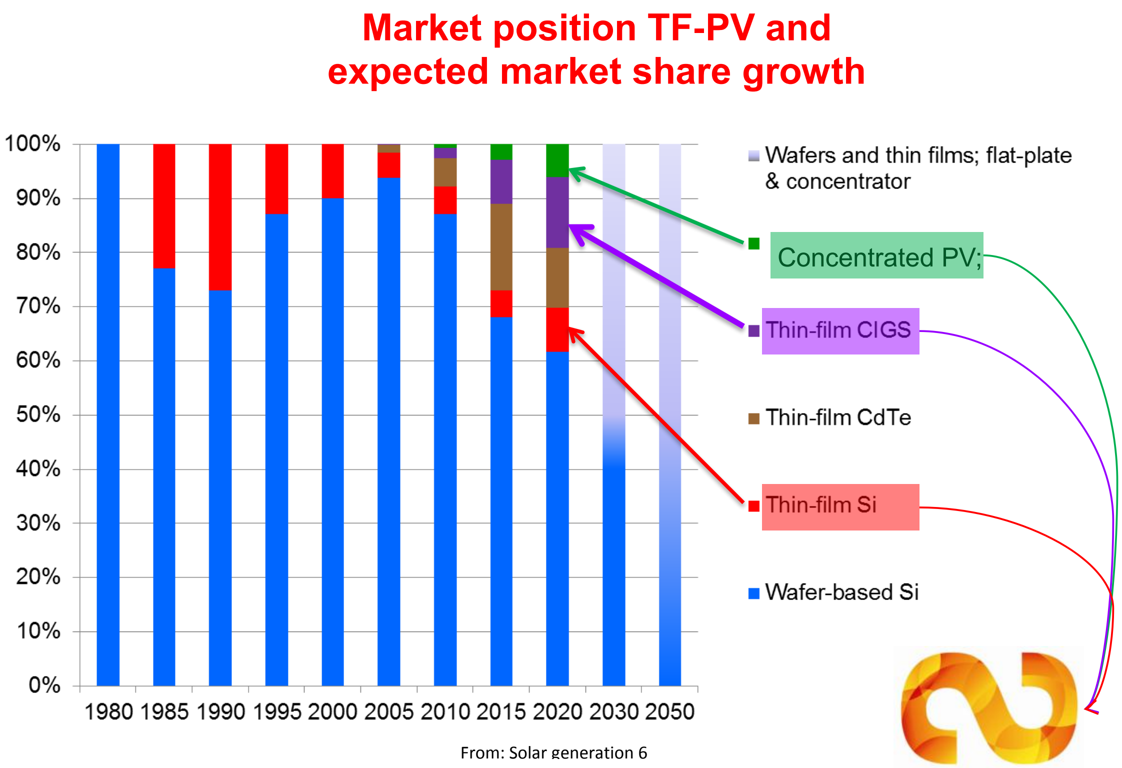

Figure 27: ***Historic and expected future market shares of PV technologies.***

2.3.1 Sub-programs

There are three basic driving forces for all types of PV cells: costs, efficiency and integral sustainability. These are ever more closely related. For thin-film technologies also the direct relation between production technologies and the application is special. It is necessary to develop the production tools in close relation with the demands of the end users. In program development, all these elements are the leading criteria from which short and long-term choices are derived. Cutthroat competition is demanding the very latest from suppliers. Aspects such as raw material shortage or objections from the point of sustainability play increasingly major roles in certain types of cells.

The research goal for 2016 for Thin-film PV is: Novel process steps to enable thin-film PV module manufacturing at cost below 0.5 €/Wp at a module efficiency of at least 10%, with a focus on low-cost (roll-to-roll) manufacturing concepts. Two Sub-programs for Thin Film PV can be distinguished:

1. Inorganic thin-film modules (**CIGS, Thin Film Si, CdTe and III-V (for concentrators)**)
   Low-cost though sophisticated manufacturing technologies implemented in industry to reduce the efficiency gap between lab scale record efficiencies and industrial module manufacturing to enable manufacturing cost below 0.5 €/Wp.

2. Organic thin-film modules (**OPV**)
   Production technology for OPV to enable manufacturing cost ultimately below 0.5 €/Wp with a focus on roll-to-roll manufacturing to achieve a step-change reduction of the Cost of Ownership.

The challenges are different for each type of cell. **Thin film Si cells** have the smallest efficiency gap between world record efficiencies and commercial module efficiencies and were the first thin film PV technology produced commercially on large scale. However a prime challenge for thin film silicon cells is to significantly increase efficiency. Cadmium Telluride (**CdTe)** is currently the cheapest technology per watt-peak, but the question is whether things can get cheaper still. Currently, the copper-indium/gallium-diselenide/sulphide (**CIGS**) technology attracts most interest because of its potentially high efficiency. The challenge here is to find new materials for the potentially scarce elements indium and gallium. In addition, the manufacturing process for CIGS is highly complex with simplification and cost reduction as major challenges. High-efficiency multi-junction **III-V** solar cells are made of gallium-arsenide-related compounds by batch-wise deposition and processing of thin, single-crystal layered structures on top of semiconductor wafers. Although efficiencies of well over 40% are obtained and they are the most efficient solar cells available, they are very expensive. For a long time they were only utilised for spacecraft applications but in recent years there is a growing interest using III-V cells for terrestrial purposes utilising light concentration systems. In the longer term, **Organic PV** is promising, due to the option of low and inexpensive material use and the possibility of printing and roll-to-roll processing. Also the possibility of tuning colour and transparency offers potential application advantages. A lot of progress is still to be made in terms of efficiency, stability and large area manufacturing processes.

2.3.2 Cross-cutting technology themes

Each thin-film PV technology is uniquely characterised by the materials used (naming the thin-film technology) and the specific stacking of layers to obtain a solar cell. However all thin-film PV technologies share a significant amount of knowledge, know-how, expertise and manufacturing technologies. These cross-cutting (generic)) technologies are the basis for manufacturing steps and thus important for industrial equipment manufacturers and material suppliers:

A. Light management through mechanical nanotexturing: OM&T/MoserBaer, VDL-ETG, C-Coatings, FOM-AMOLF;
B. Transparent conductive layers: OTB;
C. Monolithic series connection (interconnection): CCM, Stork Prints Group, Singulus Mastering;
D. Modules and integration: FujiFilm, Schaepman, van Soest;
E. Low-cost (roll-to-roll) manufacturing concepts including in-line monitoring: VDL-ETG, Meco, Smit Ovens, IBSPE;
F. Modelling, testing (incl. post-mortem failure analysis of modules) and device characterisation: Philips, Holland Innovative all partners.

2.3.3 Actions: proposed projects for 2012-2013

The combination of Sub-program lines and Cross-Cutting Technology Themes forms a matrix which is the basic structure for dynamic programming by defining projects in which industries wish to participate in the Innovation Contract, see figure below.

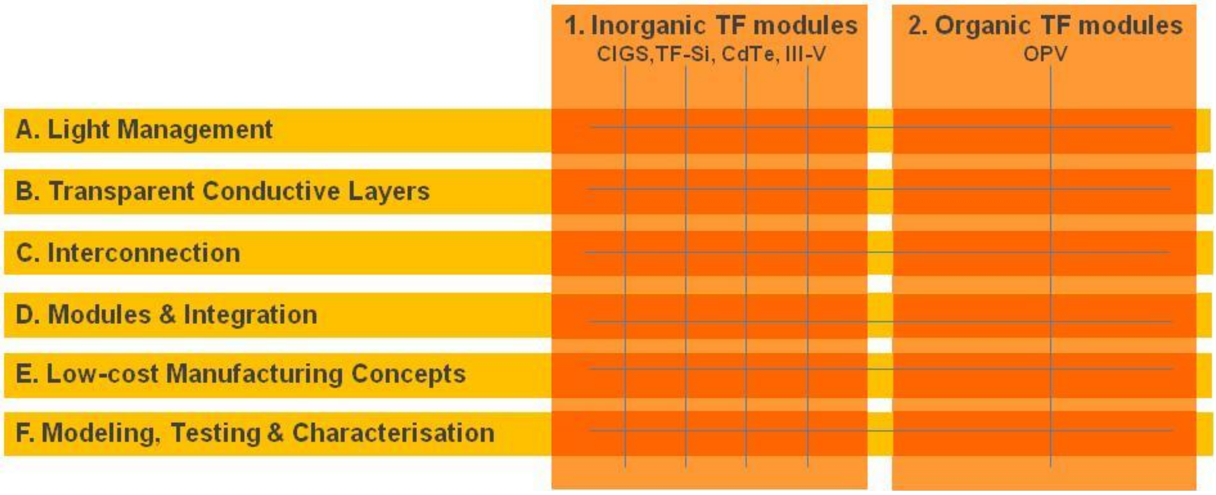

Figure 28: ***Relationships of PV module types and cross-cutting technology themes.***

Projects have been defined according to both the Sub-programs lines and the cross-cutting technology lines.

Sub-program lines

1. Non-vacuum CIGS and CZTS (copper-zinc-tin-sulphide), atmospheric selenisation and CdS replacement. The aim of the project to develop a process and equipment to deposit CIG precursor material by electro-deposition, printing or other non-vacuum techniques and to develop a process for subsequent atmospheric selenisation. Also the replacement of gallium and indium by abundantly available copper and zinc is investigated as well as the replacement of cadmium in the buffer layer.
2. Thin-film Si dynamic processing and high efficiency devices. The aim is to develop high-efficiency device concepts (multi-junction, quantum dot materials, spectral conversion) and very low-cost dynamic deposition processes (moving substrates e.g. roll-to-roll processing).
3. Roll-to-roll organic PV. The aim is to develop device concepts for atmospheric, all-solution processed OPV cells and related low-cost, high-quality production process (roll-to-roll processing).
4. High efficiency III-V devices. The aim is to develop a multi-junction cell concept for efficiencies >50% and epitaxial lift-off technology to significantly reducing cost of manufacturing the solar cells.

Cross-cutting technology themes

1. Light management. The aim is to develop a process and equipment for very effective light trapping by mechanical nano-texturisation using nano-imprint lithography.
2. Transparent conductive layers.
3. Interconnection. The aim is to develop a high-throughput process and equipment for back-end serial interconnection of thin-film solar cells (CIGS, organic PV, 'micromorph' thin-film silicon and CdTe) with a minimum loss of active area.
4. Modules & Integration. The aim is to develop modules with reduced weight, new anti-reflection coatings, flexible encapsulation and electrical connection solutions (terminal contacting). For this theme a project will be defined in due time and in synergy with the Program Line PV Systems & Applications.

The cross-cutting lines Low-cost Manufacturing Concepts and Modeling, Testing and Characterization concern predominantly knowledge and expertise exploited in the subprogram lines and currently no specific projects are defined in those themes.

2.3.4 Instruments

The proposed budget for these program lines is detailed in the table below.

Program line Thin-film PV technologies	Participating industrial organisations	Committed industry participation investm. (k€)	hours (k€)	other (k€	in cash (k€)
TOTALS		446	17.150	1.480	10.285
Thin-film PV modules	Smit Ovens, OTB, Clean Systems, Bionics, Meco, Scheuten Solar, Solmateq, VDL-ETG, Holand Innovative, Bosch-Rexroth, Stork Print Group, Clean Systems, C-Coatings, Solenne, LC Maan, GreenTech, CCM, Dutch Space, TF2 Devices, ReRa	256	11.140	1.050	10.010
Thin-film enabling technologies	OM&T, C-Coatings, OTB, Scheuten Solar, DSM, AGC, Stork Print Group, CCM, Schaepman	190	6.010	430	275

Program line Thin-film PV technologies	Participating research institutes	Institutes participation EZS (k€)	TNO (k€)	NWO (k€)	IC PV (k€)	HTS&M	EU	Total project budget (k€)
TOTALS		6.854	250	3.213	11.750	8.681	23.672	83.781
Thin-film PV modules	TNO, ECN, Tue, TUD, Holst Centre, RUG, RUN	4.797	215	2.963	8.000	7.313	19.278	65.022
Thin-film enabling technologies	ECN, TUD, Tue, TNO	2.057	35	250	3.750	1.368	4.394	18.759

For this Program Line additional budget is requested for:

1. **OPV roll-to-roll (R2R) line: 3,5 M€**
   To accelerate the development of production processes for OPV a complete roll-to-roll line is needed in which at least 3 layers are subsequently deposited. In between the layers there is a short drying step. After successful demonstration of this concept this line can be upgraded for initial small scale manufacturing as pilot line for a spin-out company.
2. **CIGS in-situ XRD: 0,5 M€**
   The main reason for the large gap between record efficiencies of lab cells and the rather low efficiencies of commercial modules is the complex phase diagram of CIGS. A novel and possible breakthrough approach is to monitor the morphology evolution during layer formation in-situ X-ray diffraction measurements. This approach might also lead to technology for in-line monitoring in production lines.
3. **Knowledge Centre Solliance (KCS): 0,5 M€**
   In the ELAt region especially there are many Small and Medium size Enterprises (SME) all with a speciality based on the strong position of the region on micro-electronics, mechatronics, photonics , software, process automation, special materials etc. Most of them are suppliers for the well known larger companies like ASML. To make optimal use of the expertise of these SME's Solliance will build up a knowledge centre (KCS) to make the participation and the use of this knowledge possible by building up a virtual knowledge centre starting a solar community, organising b2b meetings, stimulating cooperation between the most important PV regions in Europe and strengthen the position of SME's in the region in Europe. It is also found necessary to involve consumers already in an early stage, even in the stage of developing equipment for production. The Knowledge Centre Solliance (KSC) will start with a consumer panel in 2012 and will develop an open consumer application centre for PV together with them.
4. **Bridging the gap (BTG): 7,75 M€**
   It is expected that RDA+ financing as a replacement of subsidy finance from National Programmes will only start slowly in 2013. In order to avoid to have to lay off researchers and loose expertise built up in many years at the Knowledge Institutes finance is requested to bridge this (3 year) period.

3 Structure & Governance

An appropriate and fair governance structure is designed enabling independent governance and execution as well as active industry participation.

Solar Energy is a focus area in two Top Sectors: Energy and High Tech Systems & Materials (see *Figure 29* and Chapter Rationale & Scope).

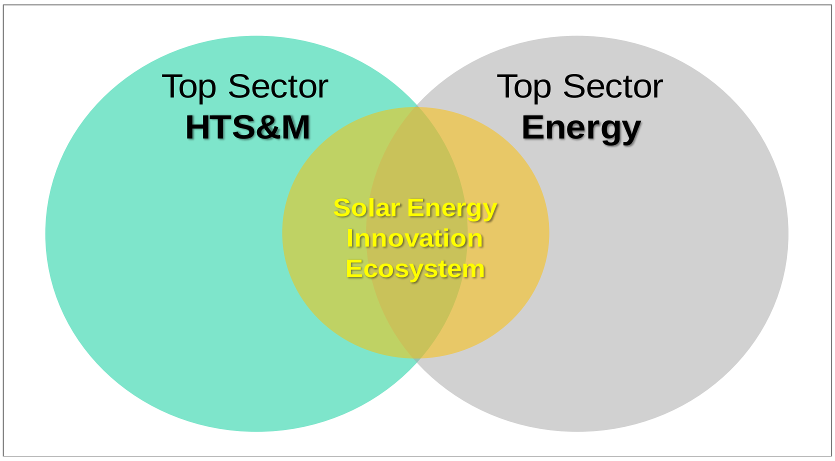

Figure 29: Solar Energy features in two Top Sectors.

The aim of both Top Sectors is to organise the entire Solar Energy Innovation Ecosystem in one entity, thus achieving maximum interaction and synergies. Moreover, this will enable the Solar Energy sector to speak with one voice, develop joint roadmaps and plans, seize national and international opportunities and demonstrate its robustness, wide scope, and size. It is therefore proposed to form one TKI (Top Consortium Knowledge and Innovation Solar Energy) with adequate substructures to make maximum use of existing organisations and initiatives. The formation of such a joint TKI, however, is subject to approval on both sides. Since the Top Sector HTS&M has not yet decided how it will organise its TKI(s), a final decision on the formation of a joint TKI cannot yet be made. The governance structure proposed, however, has sufficient flexibility to fit into several future models on the HTS&M side.

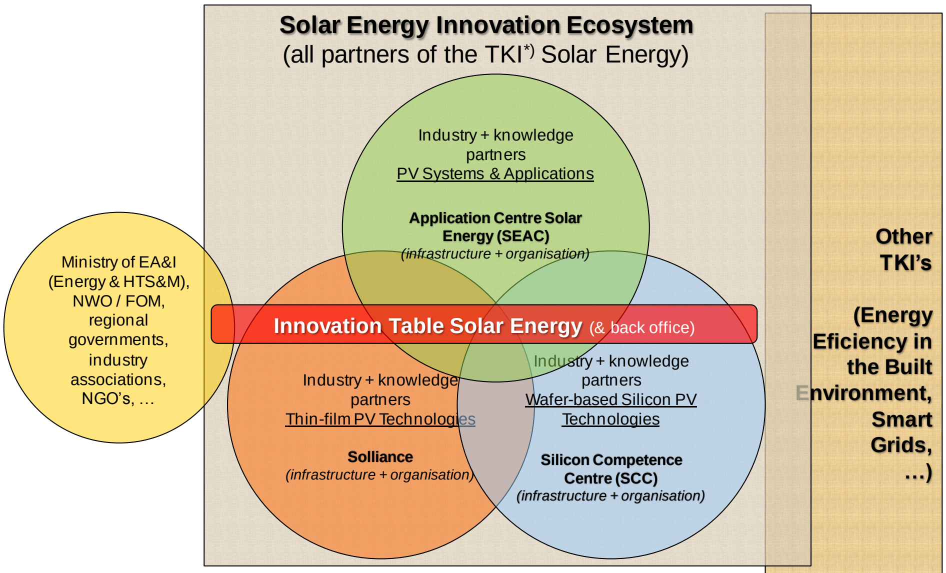

Figure 30: ***The Dutch Solar Energy Innovation Ecosystem with its substructures and relation. *)Note that the legal structure (formation of one TKI) is subject to approval in both Top Sectors dealing with Solar Energy.***

The Public-Private Partnership (PPP) TKI Solar Energy brings together all private and public partners actively involved, to execute the Programme described in the Innovation Contract(s). The legal status (subject to approval on HTS&M side) of this public-private partnership is proposed to be a "Stichting", see Figure 30 and Figure 31. The following entities are distinguished:

TKI Solar Energy: community of all TKI partners (members of the *Stichting TKI Solar Energy)*

➔ Platform for exchange of information on the highest level; elects the Chairperson of the Innovation Table with voting rights proportional to the volume of committed work within the Innovation Contract. Members are joined through signing the TKI Consortium Agreement, which defines the main procedures, rights and responsibilities, as well as the IPR framework (see separate paragraph).

Innovation Table Solar Energy (12 members + 1 Secretary + 1 Chairperson + 2 Observers)

➔ Responsible for overall programming, integration and prioritisation (incl. annual update of Innovation Plan – the program described in the Contract) and monitoring of progress (annual and/or other Reports; as required), as well as communication & formal cooperation with other TKI's and external bodies. It is also at the Innovation Table level that the interaction between Energy and HTS&M is organised (in particular through the presence of HTS&M representatives in Solliance and the roadmapping team). Decides on entry of new members or dismissal of non-performing members, based on proposals from the thematic stakeholder groups or other bodies. Procedures and voting rights to be defined. The Innovation Table Solar Energy consists of representatives from:

- the major thematic stakeholder groups (Systems & Applications – SEAC (2), Silicon Technologies – SSC (2) and Thin-film Technologies - Solliance (2));
- representatives of the roadmapping team (2);
- the government or its delegates (Ministry of EA&I and NWO/FOM - 2);
- NGO's and/or industry associations – rotating membership (2);
- secretary (from the Back Office – 1);
- independent, elected Chairperson (1).

  Further, guest memberships (observers, no voting rights) are foreseen for representatives of the TKI's Energy Efficiency in the Built Environment and Smart Grids.

SEAC, Solliance, SCC- thematically focused organisations (incl. their infrastructure)

➔ Responsible for programming and operation within their respective fields. Provide 'turn-key' input for the annual Innovation Plans and Reports. Appoint the respective delegates to the Innovation Table. Choose their own internal procedures, obeying the conditions described in the TKI Consortium Agreement.

Back office (@ ECN)

➔ Prepares annual Innovation Plans and monitors progress on behalf of Innovation Table (Innovation Reports), provides secretarial, financial and legal support to the TKI, primary point of contact with public financing organisations. Provides secretary of the Innovation Table. In view of the light nature of the governance structure, which makes full use of existing organisations, the

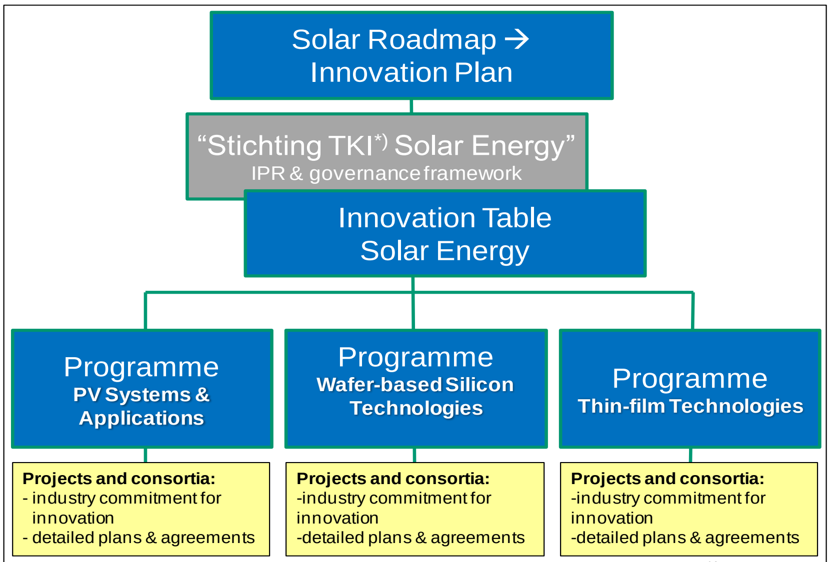

Figure 31: ***Proposed governance structure for execution of the Innovation Contract *)Note that the legal structure (formation of one TKI) is subject to approval in both Top Sectors dealing with Solar Energy.***

Dynamic portfolio management

Portfolio management on the highest level is done by the Innovation Table, by annual reviews and updates of the Program Lines (and thus the entire Innovation Contract), respecting contractual obligations (which determines the year-to-year flexibility) and boundary conditions set by the Top Team, Ministry of EA&I and NOW. Reviewing and updating includes the possibility for new partners to join the TKI and to participate in ongoing projects or new projects. Review criteria are based on milestones defined by the 3 thematic organisations and approved by the Innovation Table. Management *within* the Program Lines (Sub-programs and Projects) is the responsibility of the 3 organisations mentioned.

Intellectual property

The overall IPR framework of the TKI Solar Energy is based on existing, broadly supported practices (such as EU FP7 and FLOW). Specific conditions are:

- TKI partners participating in a project (the project consortium) should be willing and able to share results of their work with partners within the same project (without disclosing details that would hamper fair commercial exploitation of project results, see next point);
- Industry TKI partners participating in (and therefore contributing to) a project receive the right to obtain a license on IP generated by knowledge partners in that project, with an advantage (in time and/or money) over non-participating TKI industry partners;
- Detailed IPR arrangements to be made on project level.

4 Financing

(See also Annex 1)

TOTAL IC SOLAR ENERGY	Participating industrial organisations	Private funding (k€)	Participating institutes	Public funding (k€)	Totals (k€)
PV Systems & Applications		22.473		33.710	56.183
Physical integration	Oskomera, Dimark, Eternal Sun, Peerplus, Bouwend Nederland, Chematronics, KIWA, Rimas, Rollecate, Scheuten Solar, SED, SunCycle, Trespa, Tulipps, Voest Alpine, Xyztec, Yparex, Energiedak, Ballast Nedam, BDA, BOAL, Unidek, Itho, Van Campen, Green Campus, ...	9.925	UU, TUD, ECN	14.888	24.813
Electrical integration	Femtogrid, Heliox, Alrack, Alliander, Mastervolt, Scheuten Solar, SMN, Sunweb Solar, Sioux, Proxenergy, Smart Cities, KEMA, ...	12.548		18.822	31.370
Wafer-base Silicon PV Technologies		54.236		64.291	118.527
Enabling industrial manufacturing technologies	Tempress, ASM, Meco, Levitech, OTB, Eurotron, Solaytec, Sunlab	11.340	ECN, Amolf, TU Delft	35.000	46.340
High performance PV modules	Tempress, Levitech, OTB, MECO, TSC, ASM, Solaytec, Siemens, DSM, Alinement, Eurotron, OM&T, Lamers, ...	19.581	TU Delft, ECN, Amolf, TU Eindhoven,	14.391	33.972
cSi projecten 2014-2016	Tempress, Levitech, OTB, MECO, TSC, ASM, Solaytec, Siemens, DSM, Alinement, Eurotron, OM&T, Lamers, ...	23.315	TU Delft, ECN, Amolf, TU Eindhoven,	14.900	38.215
Thin-film PV Technologies		29.361		30.748	60.109
Thin-film PV modules	Smit Ovens, OTB, Clean Systems, Bionics, Meco, Scheuten Solar, Solmateq, VDL-ETG, Holand Innovative, Bosch-Rexroth, Stork Print Group, Clean Systems, C-Coatings, Solenne, LC Maan, GreenTech, CCM, Dutch Space, TF2 Devices, ReRa	22.456	TNO, ECN, Tue, TUD, Holst Centre, RUG, RUN	23.288	45.744
Thin-film enabling technologies	OM&T, C-Coatings, OTB, Scheuten Solar, DSM, AGC, Stork Print Group, CCM, Schaepman	6.905	ECN, TUD, Tue, TNO	7.460	14.365
TOTALS		106.070		128.749	234.819

4.1 Sector support

Intensive bilateral and plenary discussions with private and public partners have been organised between submission of the draft Innovation Contract on 15 December and submission of this Innovation Contract. This has led to 23 new and concrete project proposals. The financing of these projects is essential for the success of the Dutch solar energy sector. Industry is already committed with 40 new Letters of Commitment with real investments, signed by the responsible officials.

The vast majority of important stakeholders in the PV sector participate in this Contract even though detailed IPR arrangements still have to be made on a project level and actual benefits cannot be guaranteed. Many of the companies want to support the R&D infrastructure in the Netherlands because they have profited much in the past and they make clear that a real contribution to the PV market is only possible with the R&D infrastructure proposed in this Innovation Contract.
To really reap the benefits of this joint approach a true sense of urgency of all stakeholders in the "golden triangle" (or: "platinum rectangle") is needed: the developments in the global solar energy sector are extremely rapid and acting fast is crucial for commercial success. The solar energy sector looks forward to making this Contract a success to the benefit of our society!

5 Annexes

1. Financial overviews
2. Project descriptions (confidential)
3. Letters of Commitment (confidential)