SUSOLTECH

The Norwegian Research Centre for Sustainable Solar Cell Technology

Research Centre for Sustainable Solar Cell Technology

Final Report 2017-2025

Oslobygg KF

Message from the Centre Director

I have had the great pleasure of directing the Research Centre for Sustainable Solar Cell (PV) Technology (FME SUSOLTECH) from its very beginning in 2017 through to its final days of operation this year. In this final report, we summarize the main results delivered by our excellent partners from research, the public sector and the PV industry. I am deeply impressed at what the involved staff and students have been able to do, and extremely proud of the results. In this report, we will only describe selected results in any detail. It is impossible to do full justice to all the good work in the limited amount of space. Most results are described in the large number of publications and theses which are listed in the appendixes.

The pursuit of affordable and clean energy for all has set the PV industry on a record-breaking trajectory. Records for global installation rates of PV power plants have been beaten almost every year. Today, more than 2 TWp of PV capacity able to deliver approximately 10% of the global electricity demand have been installed. A record rate of ~600 GWp, or just short of 1/3 of this capacity, was installed in 2024 alone, a record which will be beaten already in 2025. This has been enabled by parallel breaking of records in both efficiency, power, sustainability and costs of PV modules. The constant breaking of records generates an extremely competitive and challenging environment for any researcher or company to work in. For the continued success of the broader PV industry and for the competitiveness of every single company, the ability to constantly innovate and improve is crucial. I am confident that research, development and innovation will continue to play leading roles in the further development of both the global, European and domestic PV industry.

For me, one of the most important motivations for getting up in the morning is the opportunity to work with and support the people involved in the fantastic PV community. I have always been particularly impressed by the ability of our industry colleagues to always go the extra mile in their efforts to stay competitive. Their underlying belief that their excellence today is no more than a good starting point for their next effort is an incredibly important inspiration. I am truly proud that FME SUSOLTECH has been able to support the record-breaking companies who have been operating out of Norway. And I am truly sad to have seen several of our best collaborators, colleagues and friends having to close down their operations in spite of their relentless effort and excellence. In the coming years, Norway and Europe will need to develop new instruments to build new, thriving industries also here. Recent history clearly shows us that ground-breaking research and record-breaking technologies are not sufficient, even when implemented in operational factories. This is deeply concerning.

In spite of these challenges there are vast opportunities ahead, as the PV industry continues its stellar growth. Norway today has a far stronger and broader PV industry than we had at the start of FME SUSOLTECH, an industry that is well positioned for further growth. However, there are no free lunches! As a good industry colleague once shared: of course it is challenging to constantly keep up with the pace of the competition! However, we know that we can compete. And each of us knows that the hours we put down every day makes an actual difference, both to our immediate colleagues, to our society and even to the future of all mankind.

We have done our best to justify the trust and resources we have received from the Research Council, our host institution IFE and our research and user partners. FME SUSOLTECH has produced research and education above our initial expectations. We also see that the work in our centre has already had a broader impact. FME SUSOLTECH has supported innovation in our partner companies and the broader domestic and European PV industry, and contributed to the generation of a large portfolio of research, development and innovation projects. We have educated more than 100 experts who are now making their own paths in research, industry and the public sector, both in Norway and beyond. And we also know that the impact of many of the results will come later, as is the nature of research and development.

Directing a research centre is a challenging task. Directing a research centre in the crazy world of PV does not make the task less challenging. In spite of this, or possibly just because of this, I am immensely grateful for the opportunity to continue in this role. As FME SUSOLTECH comes to a close, the work in our newly established Norwegian PV research centre (FME SOLAR) is rapidly gaining momentum. The best is yet to come!

Erik Stensrud Marstein
Center Director

Foreword from the host institution: IFE

This report marks the end of activity in the Research Centre for Sustainable Solar Cell Technology (FME SUSOLTECH). For IFE, as the leading research institute for research on solar energy technology in Norway, this also marks the end of eight exciting years as host of FME SUSOLTECH from our start in 2017 until today. We are pleased about what we, together with our esteemed partners from research, industry and the public sector have been able to achieve and with the overall impact the centre activities has had.

First and foremost, FME SUSOLTECH has been a research centre. As will be clear in the following pages, FME SUSOLTECH has produced research of high quality, published numerous peer-reviewed articles in leading scientific journals and made numerous contributions at the most important international conferences in the field. Education has also been a prioritised activity in the centre. FME SUSOLTECH has educated more than 100 MSc and PhD candidates and post-doctoral researchers in answer to the needs of a growing PV community, both in Norway and abroad. FME SUSOLTECH has enabled the collaborating research groups at IFE, NMBU, NTNU, SINTEF, UiA and UiO to strengthen their competence, capacity and international position in an important field, and played an instrumental role in maintaining a very good national collaboration. FME SUSOLTECH has also has played an important role in communicating the extremely rapid developments in the PV field to a broader domestic and European industry and society. In this regard, we are particularly pleased with the development and publication of the Roadmap for the Norwegian PV industry, which caught widespread attention.

FME SUSOLTECH has operated in a very exciting time. Since 2017, the use of PV power plants has grown tremendously, and is now leading the energy transition. The resulting global PV industry represents a huge commercial opportunity for innovative and internationally oriented companies. To enable Norwegian companies and research groups to compete in this extremely competitive field, we believe that national collaboration plays a crucial role: none of the research groups or companies involved are by themselves among the largest in the World, but the FME SUSOLTECH consortium as a whole has been a force to be reckoned with.

We are naturally very grateful for the support FME SUSOLTECH has received from its user and research partners. The industry involvement has directly shaped the direction of the centre, and without the financial support of all partners, FME SUSOLTECH would never have existed in the first place. We are also very grateful to the Research Council of Norway for awarding this centre funding and for maintaining a long-standing focus on solar cell technology as a topic of national importance.

The good collaboration from FME SUSOLTECH now continues in the new Norwegian PV Research Centre (FME SOLAR). IFE is very proud and happy to also host this centre, and look forward to many more years of PV research!

President
Nils Morten Huseby
Foto: IFE/Birgitte Aarebrodt, Pressure

Foreword from the Executive Board

It is with great pleasure that we present the Final report of the Research Centre for Sustainable Solar Cell (PV) Technology (FME SUSOLTECH). As we will demonstrate across the following pages, our centre has been highly successful with respect to the original plans. FME SUSOLTECH has delivered above expectations with regard to scientific production and supported the education of a large number of MSc, PhD and post-doctoral candidates, many of whom are found in the industry and research community today. FME SUSOLTECH has also been a visible centre, and worked hard to keep both the industry, public sector and a broader society updated on the rapidly developing field of PV. And FME SUSOLTECH has been a truly collaborative centre, with many of the most impressive results produced jointly by multiple research partners, often also in collaboration with our industry partners.

At the start of the activities in FME SUSOLTECH in 2017, the domestic PV industry and research activities were dominated by topics related to sustainable and low-cost production of high quality materials for the global PV industry. This part of the value chain met severe challenges due to the fierce competition, particularly from Chinese producers. Several companies who had played crucial roles in the Norwegian PV ecosystem were forced to close their operations, a severe loss for both Norway and Europe. We would like to stress that this happened in spite of the fact that several of these companies were developers and early adopters of cutting-edge technology, and best in class on important metrics both related to quality and sustainability.
In parallel, however, the broader domestic PV industry grew, particularly within development, installation and operations of PV power plants. Also recycling emerged as a new, sorely needed commercial opportunity in the PV industry. FME SUSOLTECH has supported emerging activities in these fields. Indeed, for a long-term centre, the ability to adapt to a changing environment is a key strength. We are very proud of the fact that FME SUSOLTECH has been able to develop new directions for national collaboration for the research and industry partners in these fields. As will be described in this report, FME SUSOLTECH has played an important role by contributing to the generation of a large volume of spin-off projects and activities within established fields and simultaneously ensured that the Norwegian research partners have been able to develope activities in new fields of research and development of increasing importance.

We would like to take this opportunity to share our views based on our experience from directing a long-term research FME centre in a rapidly growing but also fiercely competitive global industry. Firsly, the collaborative FME centres have multiple benefits. The long duration of these centres give sufficient time to foster national and international collaborations. It supports visibility and impact and also facilitates development of parallel research, development and innovation activities. The long term nature is also important for supporting the development of new directions of research by giving the involved research groups time and resources at an early stage. We have also been able to successfully exploit the large opportunities in the FME construction to support full-scale, industry-driven experiments, such as our industry-scale experiments on crucibles for high performance silicon material production and machine learning-based process optimization.

A challenge for FME SUSOLTECH has been that the long-term stability provided by an FME centre relies on substantial and also stable financial contributions from the user partners. The challenging years for the domestic and European PV industry necessitated the use of substantial time and resources to maintain the desired level of activity within FME SUSOLTECH. We believe that we could have delivered even more and had even more impact in a different setting. We would like to stress that our experience is that the FME centres are set up to enable sufficient flexibility in this regard, as long as the consortium as a whole is willing to adjust course.

In spite of challenging years for PV manufacturers in Norway and Europe, we see large opportunities ahead for Norwegian industry and society. The opportunities associated with supplying the growing global PV material with products, technologies and services are larger than ever. We are fortunate to have Norwegian companies along a broad value chain already competing internationally. We also have a good neighbour in the EU who works hard to establish manufacturing value chains in PV. A strong competence base remains in place in Norway to support establishment also in PV module manufacturing. Also for power production in Norway, the potential for PV to contribute is large. The ambition of 8 TWh by 2030 is increasingly hard to reach without suitable policy measures, but growth in domestic PV deployment will give both access to sorely needed power, as well as substantial value creation and employment.

We are very grateful to both the Research Council of Norway and our research and user partners for providing the large amount of funding necessary for our centre. We are also very grateful for the opportunity to continue an important national collaboration in PV through the newly granted Norwegian PV research centre (FME SOLAR). We want to continue to support the continued deployment of PV in Norway and abroad, and exploit the increasingly large commercial opportunities by building on our broad domestic PV industry combined with our excellent research groups, state-of-the-art infrastructure and national and international collaborations.

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Participants from the Final Conference at Son Spa May 19th, 2025.
Photo: Jon Arne Wilhelmsen.

Executive Summary

The Research Centre for Sustainable Solar Cell (PV) Technology (FME SUSOLTECH) was in operation from 2017 until 2025. It was hosted and led by the Institute for Energy Technology (IFE) and joined the leading Norwegian research groups in PV with a strong cluster of companies from Norway and abroad. The Norwegian research partners were IFE, NMBU, NTNU, SINTEF, the University of Agder (UiA) and the University of Oslo (UiO). FME SUSOLTECH was awarded a 120 MNOK grant and the status as a Centre for environmentally friendly energy research from the Research Council of Norway. The total centre budget also included substantial funding from the research and user partners and reached approximately 285 MNOK.

The main motivation behind the establishment of FME SUSOLTECH was to support the competitiveness of Norwegian companies involved in the rapidly growing PV industry worldwide with research and education of experts. The global PV industry offered increasing commercial opportunities along the entire value chain of PV power plant development and PV module manufacturing. A particular opportunity was identified in leveraging the unique strengths of the Norwegian process industry and research community in low-cost and sustainable production of high-performance silicon materials for PV manufacturing in the planned development of European value chains in this strategically important industry. The development of the FME SUSOLTECH application and subsequent centre was facilitated by previous collaborations among many of the

centre partners, particularly through the previous research centre FME Solar United (2009 – 2017).

FME SUSOLTECH was highly productive. The centre produced a large number of publications, including 143 articles in refereed scientific journals. Meeting the demand for skilled personnel, 15 PhD candidates, 11 post.docs and 91 MSc candidates have been educated within the centre. FME SUSOLTECH played an important role in communicating and disseminating both results from the centre itself, as well as information related to the rapidly growing global PV industry and the potential role of PV power plants also in Norway. Here, one highlight was the roadmap "Veikart for den norske solbransjen mot 2030", which caught widespread attention. FME SUSOLTECH has also played an important role in the development of a substantial volume of spin-off research, development and innovation projects. FME SUSOLTECH arranged a large number of physical and virtual meeting places for the PV community, the most important of which was the annual Norwegian Solar Cell Conference.

As the PV industry continues its growth in both Norway and abroad, so do the opportunities for both sustainable power production and value creation. FME SUSOLTECH played a crucial role in the development of the newly started Norwegian PV research centre (FME SOLAR), which is set up to support the domestic and European industry in the coming years.

Sammendrag

Forskningssenteret for bærekraftig solcelleteknologi (FME SUSOLTECH) var i drift fra 2017 til 2025. Institutt for energiteknikk (IFE) var vertskap for og ledet senteret som samlet de ledende norske forskningsmiljøene innen solcelleteknologi (PV) sammen med en sterk klynge av selskaper fra både Norge og utlandet. De norske forskningspartnerne var IFE, NMBU, NTNU, SINTEF, Universitetet i Agder (UiA) og Universitetet i Oslo (UiO). FME SUSOLTECH ble tildelt status som et Forskningssenter for Miljøvennlig Energi (FME) og ble tildelt 120 millioner kroner fra Norges forskningsråd. Det totale senterbudsjettet inkluderte også betydelig finansiering fra forsknings- og brukerpartnerne og nådde omlag 288 millioner kroner.

Hovedmotivasjonen bak etableringen av FME SUSOLTECH var å støtte konkurranseevnen til norske selskaper som var involvert i den raskt voksende globale solbransjen gjennom forskning og utdanning av eksperter. Den globale solbransjen skapte store og voksende kommersielle muligheter langs hele verdikjeden for utvikling av solkraftverk og produksjon av solcellemoduler. En spesiell mulighet ble identifisert knyttet til de unike styrkene til den norske prosessindustrien og forskningsmiljøet innen lavkost- og bærekraftig produksjon av høykvalitets silisiummaterialer for solcelleproduksjon, og i muligheten til å støtte utviklingen av europeiske verdikjeder i denne strategisk viktige industrien. Utviklingen av FME SUSOLTECH-søknaden og det påfølgende senteret var bygget på et tidligere langt og godt samarbeid mellom flere av senterpartnerne. Spesielt samarbeidet gjennom det tidligere forskningssenteret FME Solar United (2009–2017) var viktig i denne sammenheng. FME SUSOLTECH var svært produktivt. Senteret produserte et stort antall publikasjoner, inkludert 143 artikler i fagfellevurderte vitenskapelige tidsskrifter. For å møte behovet for kvalifisert personell har 15 doktorgradskandidater, 11 postdoktorer og 91 masterstudenter blitt utdannet innenfor senteret. FME SUSOLTECH spilte en viktig rolle i å formidle og spre både resultater fra senteret selv og informasjon knyttet til den raskt voksende globale solbransjen og den potensielle rollen solkraftverk kan spille også i Norge. Et høydepunkt i denne sammenhengen var lanseringen av "Veikart for den norske solbransjen mot 2030", som fikk stor oppmerksomhet. FME SUSOLTECH har også spilt en viktig rolle i utviklingen av en betydelig mengde spin-off-prosjekter innen forskning, utvikling og innovasjon. FME SUSOLTECH arrangerte et stort antall fysiske og virtuelle møteplasser for PV-miljøet, hvor den viktigste var den årlige Norske Solcellekonferansen.

Ettersom solbransjen fortsetter å vokse både i Norge og internasjonalt øker også mulighetene for både bærekraftig kraftproduksjon og verdiskaping. FME SUSOLTECH spilte en avgjørende rolle i utviklingen av det nystartede Norsk forskningssenter for solkraft (FME SOLAR), som er etablert for å støtte norsk og europeisk industri i årene som kommer.

1. Introducing the research centre FME SUSOLTECH

FME SUSOLTECH – a research centre for environmentally friendly energy research

The Research Centre for Sustainable Solar Cell (PV) Technology (FME SUSOLTECH) was in operation from 2017 until 2025. It was hosted and led by the Institute for Energy Technology (IFE) and joined the leading Norwegian research groups in PV with a strong cluster of companies from Norway and abroad. The Norwegian research partners were IFE, NMBU, NTNU, SINTEF, the University of Agder (UiA) and the University of Oslo (UiO). FME SUSOLTECH was awarded status as a so-called research centre for environmentally friendly energy research and received a 120 MNOK grant from the Research Council of Norway. The total centre budget also included substantial funding from the research and user partners. The total budget of FME SUSOLTECH reached approximately 288 MNOK.

The main motivation behind the establishment of FME SUSOLTECH was to support the competitiveness of Norwegian companies involved in the rapidly growing solar power (PV) industry worldwide with research and education of experts. The global PV industry offered increasing commercial opportunities along the entire value chain of PV power plant development and PV module manufacturing. A particular opportunity was identified in leveraging the unique strengths of the Norwegian process industry and research community in low-cost and sustainable production of high-performance silicon materials for PV manufacturing in the planned development of European value chains in this strategically important industry. The development of the FME SUSOLTECH application and subsequent centre was facilitated by previous collaborations among many of the centre partners, particularly through the previous research centre FME Solar United (2009 – 2017).

The FME SUSOLTECH consortium

In addition to the research partners IFE, NMBU, NTNU, SINTEF, UiA and UiO, FME SUSOLTECH had user partners along the broad industrial PV value chain. A particular strong-point of FME SUSOLTECH from the outset was a cluster of companies specialising in sustainable production of high-performance silicon materials for the international PV market. These companies were Dynatec Engineering, Norsun, Norwegian Crystals, REC Solar Norway, Steuler Solar Technology AS and The Quartz Corp. The German company PVA Tepla GmbH also played an important role in FME SUSOLTECH as a developer and supplier of critically important manufacturing tools. To strengthen the position of these companies in a fiercely competitive industry globally, FME SUSOLTECH targeted new production processes to obtain further reductions in costs combined with simultaneously improved material quality. A particular focus was sustainable production. Indeed sustainability permeated most centre activities and was also reflected in the centre name. Ultimately, the research and development in FME SUSOLTECH targeted cost reductions in solar power by enabling solar module efficiency increases and sustainable manufacturing by supporting innovation along the full value chain of production. Unfortunately, many of the process industry partners faced severe challenges due to extremely strong competition from the Chinese PV industry.

The second strong point of FME SUSOLTECH was the inclusion of a new research activity related to the development and subsequent operation of PV power plants, with a particular focus on PV power plants installed in buildings. Code arkitektur AS, Equinor AS, Oslobygg KF and Solenergi FUSen were active in this part of the value chain, as were the trade organizations Solenergiklyngen, Norges Bondelag and Glass- og Fasadeforeningen. At the start of FME SUSOLTECH in 2017, the volume of research, development and innovation activities in the field of PV systems in Norway was limited. The new PV system activity in FME SUSOLTECH was set up to foster national collaboration and support sustainable and cost-effective growth of an emerging domestic industry in installation and operation of PV power plants. Throughout the operation of FME SUSOLTECH, this part of the industry experienced overall rapid growth because of cost reductions of PV systems, cost increases for power, stricter environmental regulation, particularly in buildings and a renewed emphasis on increasing power production in Norway.

In the table below, the involvement of the various user partners over time is shown. Through its broad research and educational activities, FME SUSOLTECH's also aimed to support companies developing entirely new business in the field of PV. In its years of operation, FME SUSOLTECH was the most important competence and innovation platform in Norway for the growing and broad domestic PV industry.

User Partners during the center periode:

	2017	2018	2019	2020	2021	2022	2023	2024	2025
Norges Bondelag									
Code arkitektur AS									
Dynatec Engineering AS									
REC Solar Norway									
Solenergi FUSen									
Glass og Fasadeforeningen									
Norsun AS									
Norwegian Crystals									
Oslobygg KF									
PVA Crystals Growing System GmbH									
The Quartz Corp									
Equinor Energy AS									
					Solenergiklyngen				
Steuler Solar Technology AS									

Overall vision, goals and aims of FME SUSOLTECH

The overall vision of FME SUSOLTECH was to support further growth of a broad, domestic PV industry by ensuring future competitiveness through innovation. A concrete goal of FME SUSOLTECH was to increase the size and number of jobs in the domestic PV industry. To support this overall goal, FME SUSOLTECH included the following list of secondary goals.

1. **To develop the most environmentally friendly production processes for Si feedstock for high efficiency, crystalline Si-based solar cells in the World.**
2. **To develop processes for making affordable, high performance Si ingots and wafers, as well as selected materials and processes allowing for producing solar cells with efficiencies above 25% for Cz Si and 21% for HPMC Si.**
3. **To demonstrate lower electricity costs, improved performance and improved sustainability due to the developed technologies on cell, module and system level.**
4. **To contribute to a cost-effective and sustainable growth in the use of solar energy systems in Norway, with a particular emphasis on the building sector.**
5. **To establish a Solar Industry Forum which will generate new business, projects and activities among the industry and research partners in the Centre.**

We are proud to report that FME SUSOLTECH, through a large, joint effort by the research and user partners, successfully reached all of these secondary goals.

In Norway, a major shift occurred during the years of centre operation. While the domestic industry at the outset was dominated by companies targeting the value chain of PV manufacturing, this part of the industry faced severe challenges in the face of Chinese competition. However, companies targeting or supporting development, installation and operation of PV power plants in Norway and abroad experienced substantial growth. The domestic PV industry is therefore larger that at the outset of FME SUSOLTECH, but with a different and also broader focus. FME SUSOLTECH included a new national research collaboration dedicated to PV power plants, which increased in importance over time. Moreover, FME SUSOLTECH has been sufficiently flexible as to handle changes in the consortium and shifts of priorities and topics over the years. The centre has therefore remained able to deliver high quality research and education in spite of a turbulent environment. FME SUSOLTECH contributed to the development of a substantial volume of surrounding R&D and innovation activities in the field of PV power plants. FME SUSOLTECH became the origin of the follow-up research centre FME SOLAR (2024 – 2032), where R&D related to PV systems is the core.

Research in FME SUSOECH

Research activities were at the heart of FME SUSOLTECH. These were highly productive, resulting in a large number of publications. In addition, it was instrumental in shaping a substantial, surrounding volume of research, development and innovation projects. The research activities involved both research and user partners. They benefited substantially from access to state-of-the-art infrastructure including the Norwegian laboratory for silicon-based solar cell technology, NORFAB and various infrastructure funded through FME Solar United and FME SUSOLTECH. The overall production of the research and development activity, as well as selected highlights will be described in more detail in later sections in this report. To structure this core activity, the research in FME SUSOLTECH was organized in four Work Packages (WP2), each open to all partners:

- **WP1: Sustainable silicon feedstock production**
- **WP2: High quality silicon ingots and wafers**
- **WP3: Highly efficient silicon solar cells and modules**
- **WP4: End use and impact**

Education and training in FME SUSOLTECH

With an anticipated growth of a broad domestic PV industry, so was an increasing need for competence and capacity. Education and training of MSc candidates, PhD candidates and post.docs was therefore an important activity of FME SUSOLTECH. In later sections in this report more information about this activity will be given. A full list of the candidates is given in Appendix 2.

Communication and dissemination in FME SUSOLTECH

With the PV industry playing an increasingly important role both globally and in Norway, another important aim was associated with broader dissemination and publication. To this end, FME SUSOLTECH arranged meeting places for the Norwegian solar cell community, including the Norwegian Solar Cell Conference (NSCC) and meetings and webinars focusing on industry-relevant topics. Many of these were arranged in collaboration with the Norwegian Solar Energy Cluster (Solenergiklyngen). More information about this activity will follow in later chapters. A full list of popular scientific contributions is given in Appendix 3.

The organisation of FME SUSOLTECH

The operation of FME SUSOLTECH was supported by an efficient organization, which will be briefly described here and is shown in the figure below. The upper decision making body of FME SUSOLTECH was the General Assembly, where all partners were represented. The day-to-day direction of the center was supported by a 9 member Executive Board where five of the members were selected from the user partners and 4 from the research partners. The Research Council of Norway was an observer in the Executive Board meetings. Professor Erik Stensrud Marstein (IFE) was the director of FME SUSOLTECH from 2017 until 2025. In the daily direction, management and operation of FME SUSOLTECH, he was supported by a deputy director, the centre coordinator, four work package managers and administrative staff. The four largest research partners of FME SUSOLTECH: IFE, NTNU, SINTEF and the University of Oslo were represented in the centre management team.

Picture of the FME SUSOLTECH Center Management team (CMT) and members of the Executive Board (EB) (Photo Jon Arne Wilhelmsen)
From the left Merete Estensen (CMT), Birgit Hernes (The research council of Norway), Erik Stensrud Marstein (CMT), Øystein Prytz (EB), Heine Nygaard Riise (CMT), Torunn Kjeldstad (CMT), Rudie Spooren (EB), Mari Juel (CMT), Eduard Monakhov (CMT), Kristin Bergum (CMT), Per-Anders Hansen (CMT), Marisa Di Sabatino (CMT)

The daily operation of FME SUSOLTECH

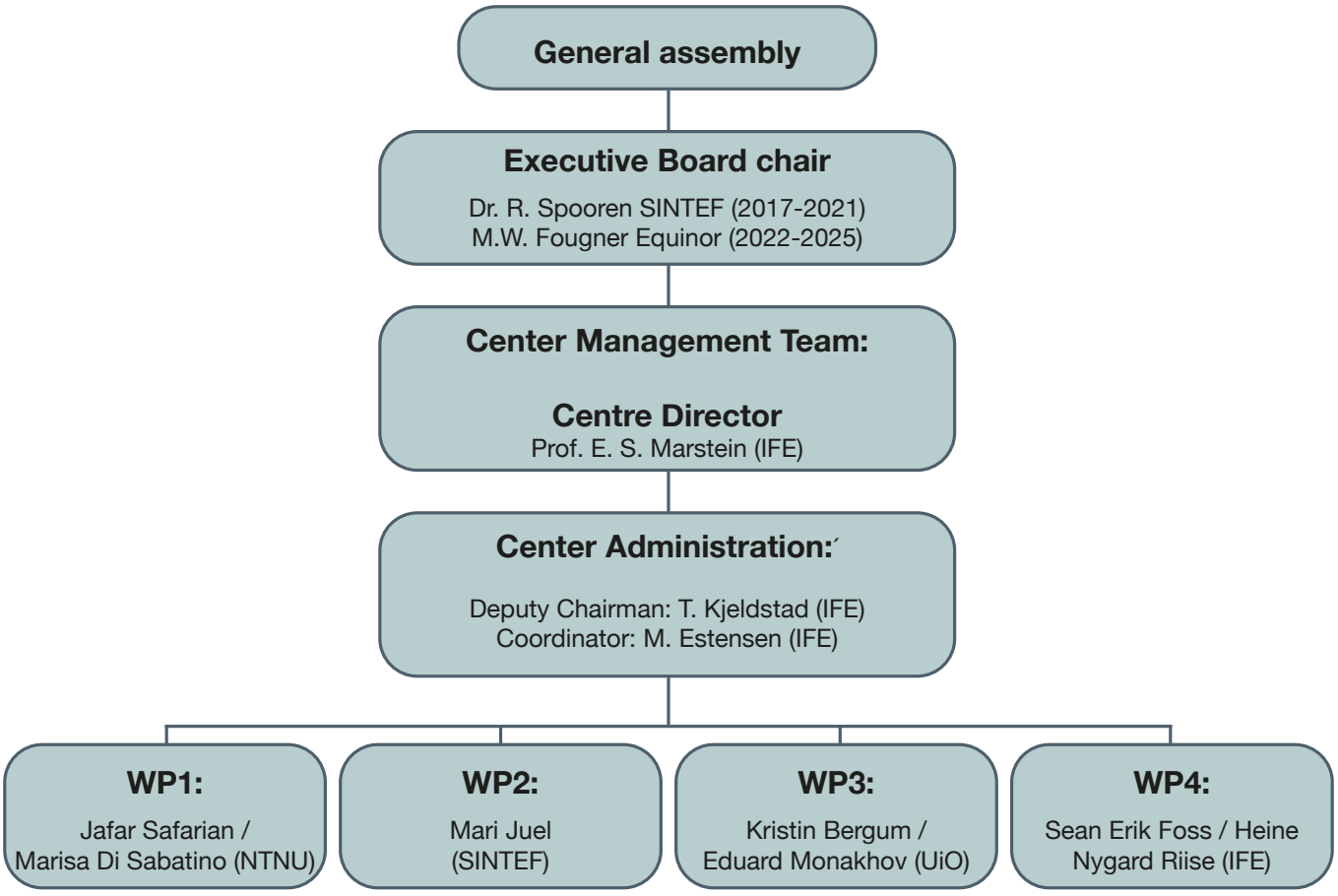
Work in FME SUSOLTECH was performed by many partners working from a number of different locations and involved a large number of people. It was therefore important to establish effective means for communication and collaboration.

The most important basis for the daily operation was the annual Work Plan. Every year, this plan with defined activities, milestones and deliverables was developed in a process led by the centre management team and involving all partners. Dedicated meetings were arranged and open to all partners to enable all to contribute to and comment on the content. The responsibility of approving the Work Plan was given to the Executive Board. In the context of the midway evaluation of FME SUSOLTECH, the overall strategy and long-term plan was revisited and a revised plan for the last 3 years of the centre developed and approved.

Most daily work and collaboration took place within specific tasks in each work package. Work package meetings were arranged several times per year to discuss tasks, collaborations, progress and plans. FME SUSOLTECH was also responsible for arranging the Norwegian Solar Cell Conference, the most important meeting place for the PV R&D community in Norway, open to all with an interest in PV science and technology in Norway. The centre also arranged an Annual Meeting to enable all partners to follow and comment on the centre production. In addition came other dedicated meetings and events.

A particular challenge facing FME SUSOLTECH was that it was in operation during the highly disruptive COVID epidemic. This accelerated the use of virtual meeting platforms. These became particularly important for the large number of international candidates, most of whom had a limited local network and suddenly faced severely limited access to both work places and colleagues. The centre management established new, virtual meeting places as a back-up community, particularly aimed at the affected PhD and post.doc candidates in the centre.

The Centre organization is shown in the figure below:



2. The FME SUSOLTECH finances

The activities in FME SUSOLTECH were a large joint effort supported by a 120 MNOK grant from the Research Council of Norway (RCN) and large contributions from the research and user partners. The total centre budget reached approximately 285 MNOK. In the table below, a summary of the financing of FME SUSOLTECH is shown.

Securing sufficient user partner financing to leverage the RCN grant became an increasingly important challenge for FME SUSOLTECH due to the challenging competitive environment facing many of the centre partners. While the centre in the application and first years of operation received user partner financing exceeding the required level to leverage the grant, several partners eventually left the centre and others needed to reduce their contributions. This made the job of identifying and securing sufficient user partner contributions increasingly important. A substantial part of both the centre management and the Executive Board capacity was needed for this purpose. Fortunately, due to a large joint effort and commitment by the partners, FME SUSOLTECH was ultimately able to leverage the major part of the original grant.

3. The overall production of FME SUSOLTECH

FME SUSOLTECH has been a highly productive centre, both in terms of scientific publications in refereed journals, presentations at national and international conferences and workshops, as well as in education and training of experts in PV, among others through the education of MSc and PhD candidates. FME SUSOLTECH has also supported innovation and value creation, both directly through the development of relevant results in this aspect, but even more importantly through a large effort related to supporting surrounding industry and innovation projects.

In the table below, a summary of the overall results from the activities in FME SUSOLTECH are given in line with the taxonomy used by the Research Council of Norway. Selected results will be described in more detail in the coming chapters.

	2017	2018	2019	2020	2021	2022	2023	2024	2025	Total
Articles in refereed journals	8	7	11	19	23	21	23	20	11	143
Presentations in mass media		10	11	9	38	34	36	24		162
PhD theses (finished)		1		1	3	3	2		1	11
Master theses (finished)	1	9	12	7	14	18	14	14	4	93
Presentations at international scientific conferences	5	9	5	6	18	15	14	15	8	95
Reports and presentation at technical meetings		2	4	28	10	29	6	14	12	105
Reports, lectures, articles and, presentations for public sector, business, and industry	7	48	39	6	93	38	43	52	12	338
Communication effort towards relevant target group		18	4	14	3		12			51
New or improved methods, models and prototypes		5	5			2	2			14
New or improved products, processes and services		3	1	1	3	4		1		13

4. Highlights from the research in FME SUSOLTECH

The research and development activities in FME SUSOLTECH were selected to align with the current and anticipated needs of the domestic PV industry and Norwegian society, and the research partner competence and strategy, and aimed at shifting the frontier of science and technology. As previously mentioned, the research and development activities were organized in four Work Packages (WPs) covering sustainable silicon feedstock production (WP1), high quality silicon ingots and wafers WP2), highly efficient silicon solar cells and modules (WP3) and end use and impact (WP4).

In the following, selected highlights from each of these WPs will be presented in more detail. A comprehensive insight into the scientific production of FME SUSOLTECH is found in the lists of published papers, presentations and theses in Appendix 3. The research in FME SUSOLTECH has also been important for the generation of surrounding activity. Spin-out projects building on the new knowledge, methods, capacity and infrastructure from FME SUSOLTECH are shown in Appendix 4.

Sustainable Silicon Feedstock Production

Introduction

At the time of writing, 98% of all solar cells produced in the world are made from silicon. The production of high purity silicon feedstock materials is both challenging and energy intensive. The research activity on sustainable silicon feedstock production in FME SUSOLTECH focused on enabling sustainable and affordable production of silicon while maintaining the extremely high material quality necessary for use in modern high efficiency solar cells and modules. The activity combined research groups at the international scientific frontier with domestic companies commercializing proprietary production processes for such materials, enabling cutting-edge research. Initially the activity covered both chemical- and metallurgical routes, but after a few years it was entirely switched toward the metallurgical route to support the activities of the company REC Solar Norway in this field. The use of recycled silicon became increasingly important in the later years of operation of FME SUSOLTECH. In addition to permanent staff from both the research and industry partners, a number of MSc and 4 PhD candidates have carried out the research work.

Education and dissemination was prioritized in this activity. An intensive two-day course "Theory and Processes for Solar Grade Silicon Production" was arranged in Trondheim by FME SUSOLTECH in 2018 and 2019. In 2019, FME SUSOLTECH also arranged the seminar "Material loss and recycling in the whole value chain for PV silicon production and use". FME SUSOLTECH also supported the international workshop "Refining and recycling of solar silicon" in Trondheim in 2022. A picture from this workshop is shown below.

This activity was performed within WP1, which was initially led by professor Jafar Safarian from NTNU. This role was taken over by professor Marisa Di Sabatino. For her broad commitment so sustainable production, she was awarded the NTNU Faculty of Natural Sciences Sustainability Award in 2023.

Participants in the international seminar on "Refining and recycling of solar silicon" in Trondheim in 2022.

Silicon purification and refining

A core activity in WP1 in FME SUSOLTECH was research and development of new methods for silicon purification and refining. This activity involved 4 PhD candidates at NTNU. In 2022, Arman Hoseinpur Kermani defended his PhD thesis at NTNU titled "Vacuum and Gas Refining of Silicon for Solar Cell Applications". In his work, Arman did experimental and theoretical work on vacuum metallurgy and gas refining of silicon, work that resulted in 7 journal papers. Arman's work contributed to an improved understanding of the behaviour of phosporous (P) and silicon (Si) atoms near the melt surface at low gas pressures. A schematic illustration of this is shown below. Arman developed and applied innovative approaches for improving the rate of vacuum refining and minimising energy consumption. The experimental work was complemented and supported by atomistic modelling of the key mechanisms involved.

Also in 2022, Mengyi Zhu defended his PhD thesis titled "Silicon purification by acid leaching and slag refining techniques" at NTNU. Mengyi performed experimental and theoretical work on a novel approach for silicon purification based on the intentional addition of calcium (Ca) or magnesium (Mg) to the silicon materials followed by solidification and subsequent acid leaching to purify the alloys. He modelled the process using fundamental approaches and employing molecular dynamics. He also investigated the opportunities for purification using refining of silicon and recycled silicon-kerf materials. His research resulted in 6 journal papers.

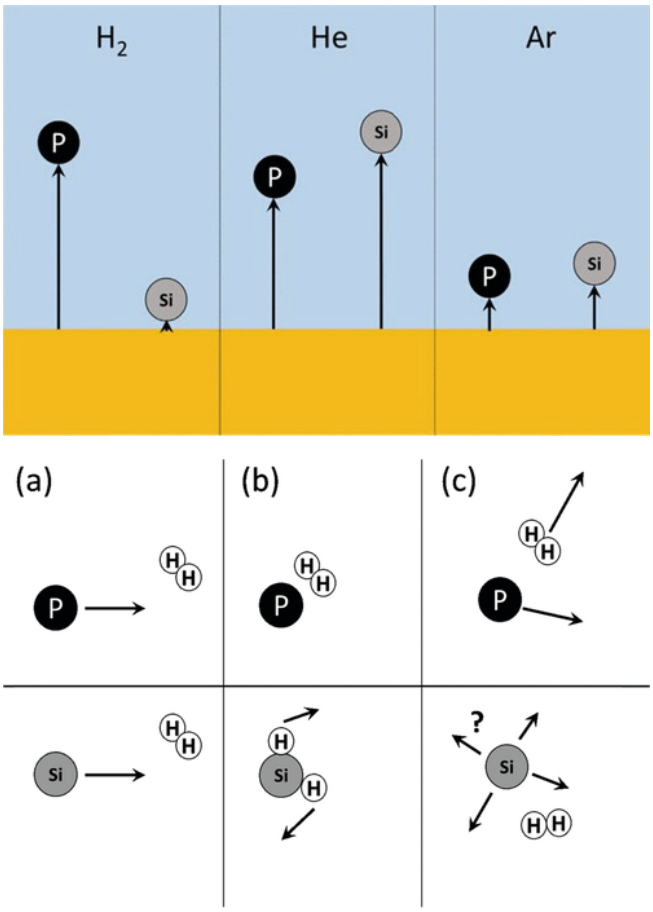
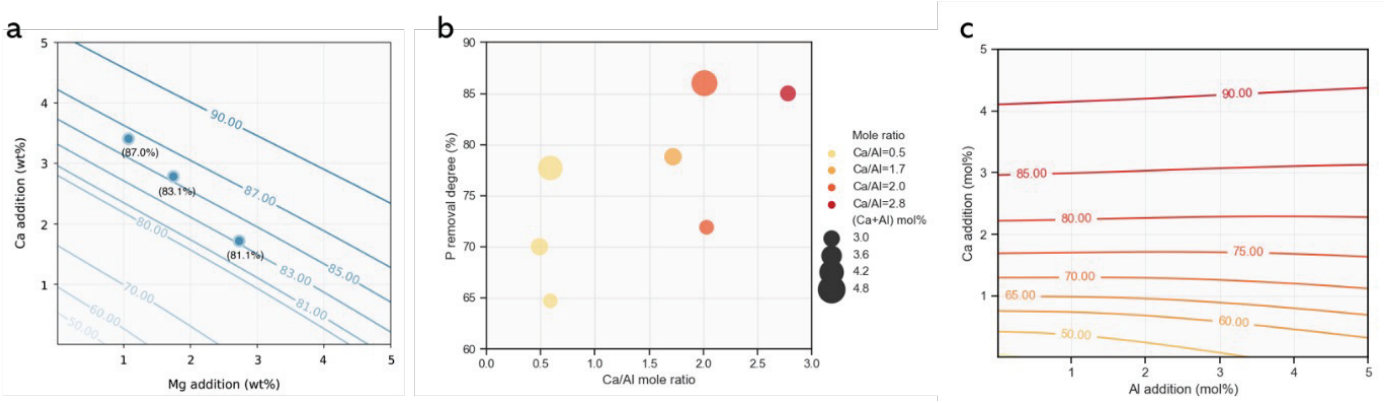
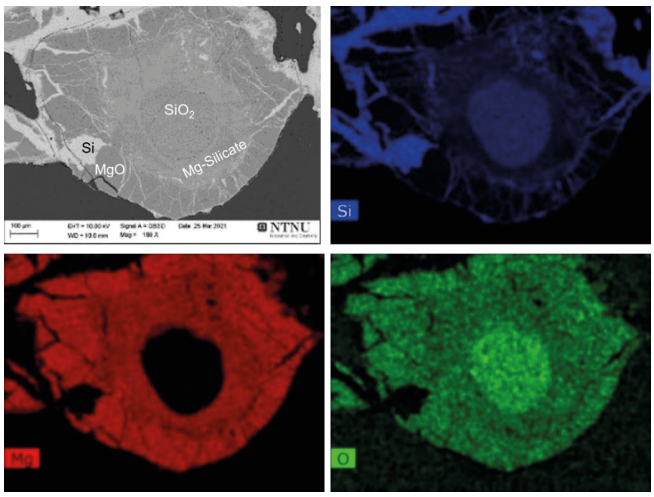


Illustration of transport of P and Si atoms under different gases (left). Typical collisions of P and Si with H2: (a) initial state, (b) closest encounter, and (c) final state (right). (Source: Arman Hoseinpur Kermani/NTNU and Stefan Andersson/SINTEF).



(a) P removal model for the Si-Ca-Mg ternary system, (b) P removal results after leaching of Si-Ca-Al alloys, (c) Obtained P removal model for Si-Ca-Al system. (Source: Mengyi Zhu`s PhD Thesis (2021))

In 2023, Azam Rasouli defended her PhD thesis titled "Synthesis of Mg2Si and its use for Silane production" at NTNU. Her work included both experimental and theoretical studies on the high temperature synthesis of Mg2Si from silicon dioxide (SiO2) and Mg metal mixtures, outlining the mechanism and optimum conditions for such synthesis. Her work involved collaboration with IFE on the hydrolysis of the produced Mg2Si to directly generate- and analyse SiH4 (silane) gas, an important process gas for a wide range of industries, including the PV industry. Azam's work resulted in 4 journal papers.



Backscattered electron images together with X-ray mapping of Si, Mg and O elements in a quartz particle interacted with Mg. (Source: Azam Rasouli's PhD Thesis (2023))

Tinotenda Mubaiwa is pursuing his PhD thesis titled "Si-kerf recycling". His research work focuses on recycling of Si kerf, an important waste material from the process industry, and includes both characterisation and subsequent purification of this material. Tinotenda has performed kerf purification using acid leaching as a pretreatment step and investigated the use of high temperature melting of the Si kerf under different conditions to purify the material. He has shown that most of the metallic impurities as well as P can be removed by acid leaching. Blending of solid silicon granules with silicon kerf powder was applied and significantly improved the melting behavior of Si kerf. Tinotenda has published one journal paper and 3 conference proceedings. He will deliver his PhD thesis in the Fall 2025 at NTNU.

Advanced material characterisation and materials modelling
Silicon materials for PV applications require extremely high purity. This makes detection and quantification of any remaining impurities in the material very challenging. UiO has supported researchers and candidates from NTNU, SINTEF and the other partners in WP1 in their the development of new processes for purification and recycling of silicon materials with the advanced characterisation techniques available in the UiO MiNaLab. These include secondary ion mass spectrometry (SIMS), which has been used for impurity characterisation of Si and Si-based alloys. In FME SUSOLTECH, a particular attention has been paid to elemental mapping using SIMS.

Colleagues from SINTEF have supported the research activities in WP1 by thermodynamical simulations, and have made important contributions to all the involved PhD candidates. In recent years, the activities have shifted towards machine learning-based modeling of the silicon feedstock production processes. The figure below shows a figure from a recent paper by SINTEF and NTNU colleagues combining experimental work with modelling.

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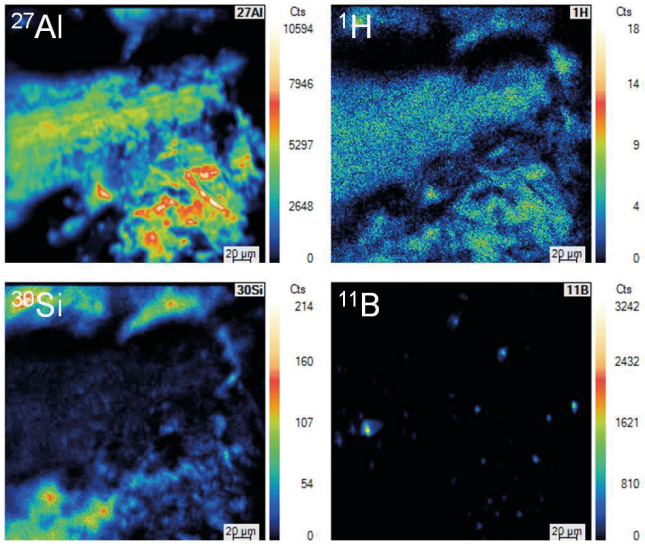
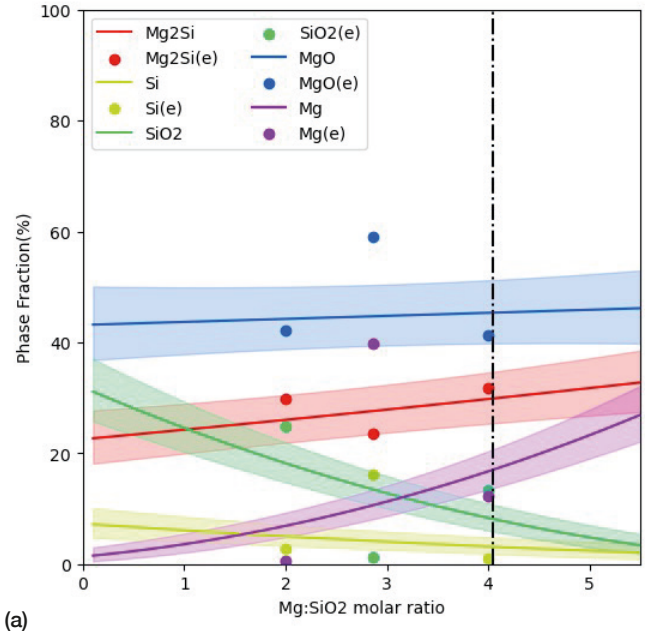
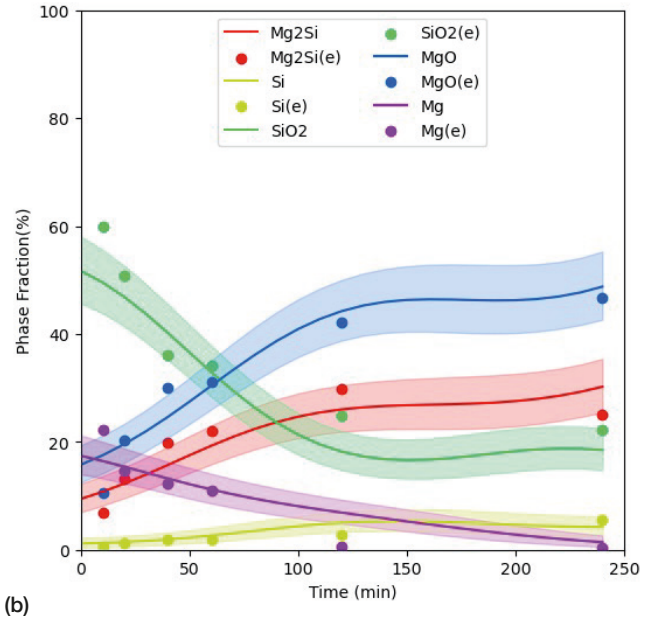


2D SIMS maps of the impurities Boron (B) and Hydrogen (H) as well as the main elements Si and Aluminum (Al) in a SiAl alloy.

Colleagues from SINTEF have supported the research activities in WP1 by thermodynamical simulations, and have made important contributions to all the involved PhD candidates. In recent years, the activities have shifted towards machine learning-based modeling of the silicon feedstock production processes. The figure below shows a figure from a recent paper by SINTEF and NTNU colleagues combining experimental work with modelling.



(a)



(b)

(a) Phase fractions of species at 1173 K for varying Mg/SiO2 molar ratios. (b) Comparison of calculated and measured species variations as functions of the reaction time at Mg/SiO2 ratios of 2 and 2.9 at 1173 K. (Source: T. Kai et al., A. Rasouli, J. Safarian, X. Ma and G. Tranell, "Magnesiothermic Reduction of Silica: A Machine Learning Study" Materials (2023))

High performance silicon ingots and wafers

Introduction

The production of high efficiency silicon solar cells and modules is impossible to achieve without access to silicon wafers of extremely high material quality. The material quality depends on the silicon feedstock, crucible and furnace materials, as well as the crystallisation process itself. The continued pressure to reduce costs while supporting manufacturing of silicon solar cells with ever-increasing efficiencies makes the development of improved crystallisation processes enabling low cost production of high quality silicon ingots and wafers crucial. This can only be achieved with a deep understanding of the root causes of any harmful impurities and their transport into the silicon materials, as well as the formation of defect in the silicon material. The exact influence of impurities and defects on the electrical properties of silicon solar cells must also be understood. By building this knowledge, the research partners in FME SUSOLTECH in collaboration with leading companies in this part of the industrial value chain have made many important contributions to the development of improved crystallisation processes and processes for subsequent handling of impurities.

The tight collaboration between the research and user partners in FME SUSOLTECH's WP2 enabled the Norwegian research community and industry to maintain an international leading role in the industrially important field of silicon crystallisation. During the years of FME SUSOLTECH's operation, the requirements for wafers have changed dramatically. While B-doped, p-type wafers made from multicrystalline silicon held large market shares in 2017, at the time of writing the industry is switching to P-doped, n-type wafers made from monocrystalline silicon. The FME SUSOLTECH consortium has demonstrated a strong ability to adapt to new trends and made it possible for the Norwegian ingot and wafer producers to remain in the market much longer than most of their European competitors.

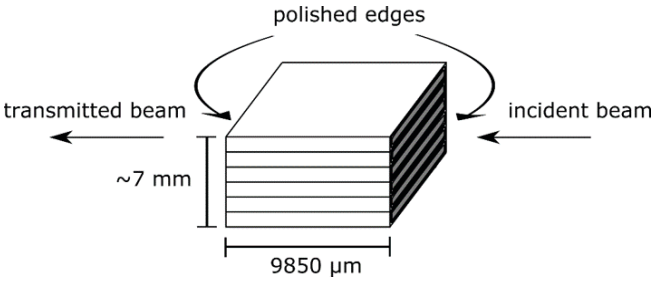
WP2 was led by Mari Juel from SINTEF.

Hydrogen in silicon wafers

Hydrogen (H) can bond with virtually everything and is therefore widely used for reducing harmful effects of defects and impurities in silicon solar cells. The effects of hydrogen on the silicon quality can easily be seen through the performance of solar cells. However, it is notoriously difficult to study H in bulk silicon directly. Most applicable methods simply lack the sensitivity to study the low concentrations of H in silicon. Therefore, it was a big achievement in 2019 when researchers from UiO and IFE

were able to measure hydrogen complexes in silicon by the use of low temperature Fourier-transformed infra-red spectrometry (FTIR) in silicon wafers stacked on top of each other. This method represented a much-needed tool for studying H in bulk silicon directly and received much international attention. Since the original publication, the method has been further developed and is now used both in collaboration with industry partners and international research partners.

PhD candidate Nicole Aßmann from the University has been responsible for this research in recent years. Her work has already resulted in several publications and increased international visibility.



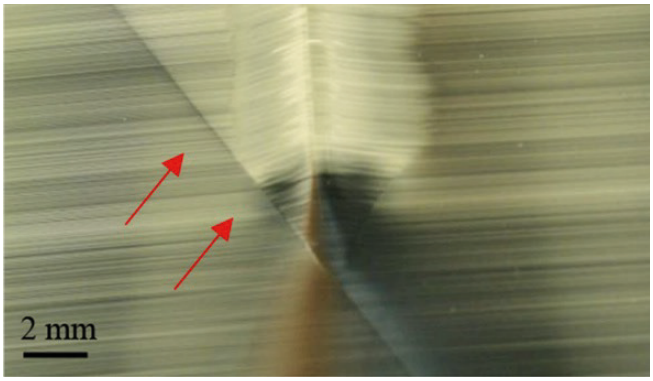
Hydrogenated silicon wafers cut into 1x1 cm2 wafer pieces and polished on the edges. IR transmittance spectra are obtained longitudinally using a Bruker spectrometer (Source: UiO)

Crucible properties

A high priority in the center has been to improve the understanding of how the quality of the crucibles used during silicon crystallisation influence the productivity and material quality of monocrystalline (Cz) silicon production. In close collaboration between user and research partners in FME SUSOLTECH we have investigated how different treatments of quartz sand influence critical quartz glass properties such as viscosity and bubble growth. The center collaboration made it possible to test crucibles made of different quartz sand quality from TQC in industrial scale pulling experiments at Norsun followed by characterisation at SINTEF and NTNU. These unique experiments gave valuable insights both to TQC on how to improve their sand treatment and to Norsun on how to select and handle crucibles during ingot production. The knowledge on crucibles has further been strengthened though the work of PhD candidate Gabriela Warden from NTNU, as well as parallel MSc work. Gabriela's research has given valuable insights into how variations in the uniformity of the crucible and contact materials are influencing the crucible performance, and has resulted in several publications. Gabriela also won a prestigious student award at the important conference EUPVSEC..

Structure loss in monocrystalline silicon (Cz-Si) production

Structure loss in Cz-Si ingots is a type of defect that causes both productivity and yield losses. A stated goal of FME SUSOLTECH from the outset was to solve the problem associated with yield-limiting structure loss during Cz-Si production. Two post-docs at NTNU have worked on this topic in close collaboration with SINTEF and the involved user partners. An important outcome of this work is a non-destructive method for identification of the root cause of structure loss. Four main root cause categories have been identified and are illustrated in the fishbone diagram. This diagram also includes potential parameters that can influence the occurrence of the different categories. SINTEF supported this activity with machine learning methods for classification.



An example of how the growth ridge indicating monocrystalline Cz-growth stops due to a slip line caused by a dislocation. (Source: Hendawi, R., Di Sabatino, Marisa, "Analyzing structure loss in Czochralski silicon growth: Root causes investigation through surface examination" Journal of Crystal Growth (2024))

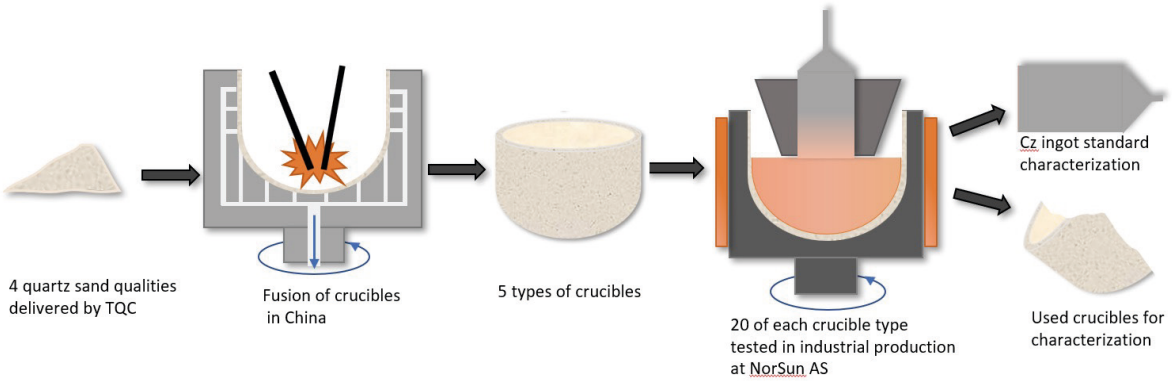
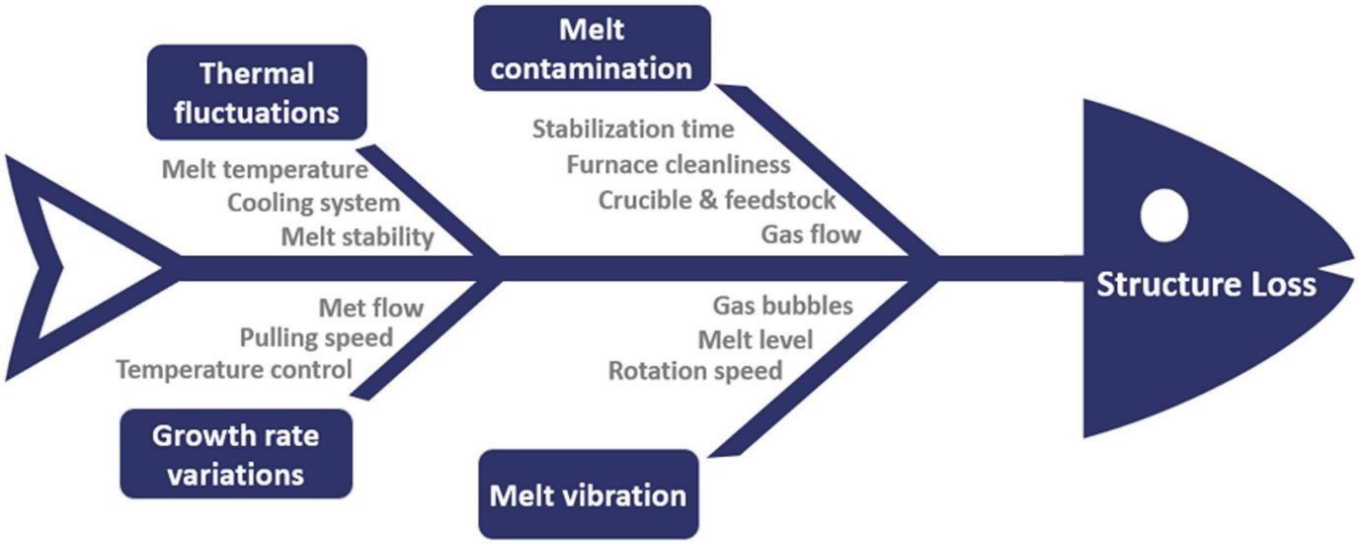


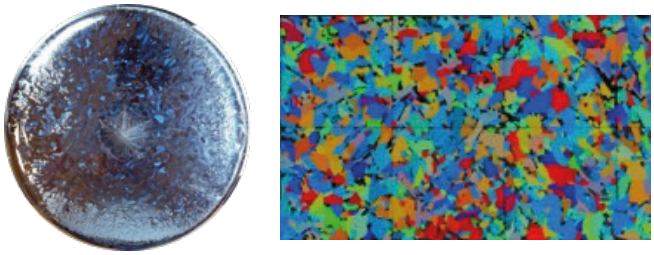
Figure 2. Industrial scale crucible experiment performed in FME SUSOLTECH



The main root causes for structure loss in Cz growth of silicon ingots is illustrated in a fishbone diagram. (Source: Hendawi, R., Di Sabatino, Marisa, "Analyzing structure loss in Czochralski silicon growth: Root causes investigation through surface examination" Journal of Crystal Growth (2024))

High performance multicrystalline (HPMC) silicon

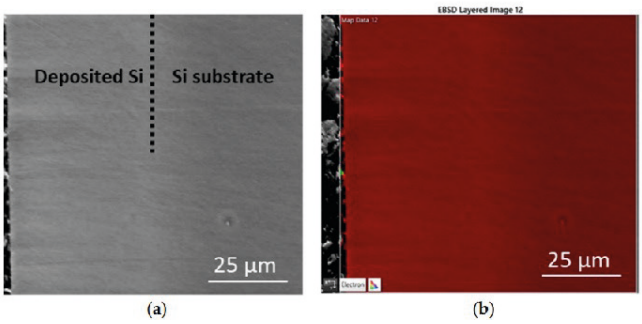
At the start of center operations in 2017, the leading method for producing multicrystalline silicon was known as high performance MC (HPMC). Research in FME SUSOLTECH contributed to an improved understanding of how producers could control the nucleation and growth in of silicon crystals by using pioneering in-situ experiments on the generation, transport, pinning and mitigation of the very important defect type dislocations during the ingot growth. Due to changing market trends, the activity on crystallisation of multicrystalline Si was discontinued in FME SUSOLTECH in 2021 in order to strategically channel resources towards the market leading Cz-Si technologies discussed above.



High performance multicrystalline silcon ingot and grain structure measured with Laue tool (Source: SINTEF).

Kerfless silicon

Today, all produced silicon solar cells and modules rely on the use of silicon wafers made by a sawing process, which results in significant yield losses due to the resulting silicon kerf. Methods for production of kerfless silicon wafers can increase the yield in wafer production significantly. In FME SUSOLTECH, electron beam evaporation was successfully used to produce wafers directly. Fully crystalline p-doped silicon films have been grown on silicon substrates at a high deposition rate of ~1.5 µm/min at 1000 °C. This activity has demonstrated that electron beam evaporation can be used to grow silicon layers and potentially also free-standing silicon wafers.



Electron beam deposition of silicon at SINTEF. Cross section of layer deposited at 1000 °C, (a) SEM image and (b) SEM image with the IPF-x (inverse pole figure) colour from the EBSD overlayed. (Source; M. Stange, T.O. Sunde, R. Dahl-Hansen, K. Rajput, J.S. Graff, B.D. Belle and A.G. Ulyashin, "High-Rate Epitaxial Growth of Silicon Using Electron Beam Evaporation at High Temperatures" Coatings (2023).

High efficiency silicon solar cells and modules

Introduction

This important part of the value chain was performed in WP3 and divided into three tasks. The first task on silicon wafers for high efficiency solar cells addressed the impact of different processing steps and field operation on wafer quality and efficiency. The goals of this task were:

1. **To develop methods for assessing efficiency potential and degradation based on data from ingot and wafer production**
2. **To quantify light-induced degradation in silicon wafers and solar cells and to develop suitable regeneration processes to avoid this degradation**

The second task targeted beyond 25% efficiency crystalline silicon solar cells through the development of high efficiency solar cells approaching or exceeding the fundamental Shockley-Queisser limit for silicon solar cells of ~30%. The goals for this task were:

1. **To develop new, robust processes for surface passivation in the single-junction silicon solar cells, including passivated contacts**
2. **To develop photon energy conversion materials applicable for solar cell and/or module production**
3. **To develop efficient silicon-based tandem solar cells**

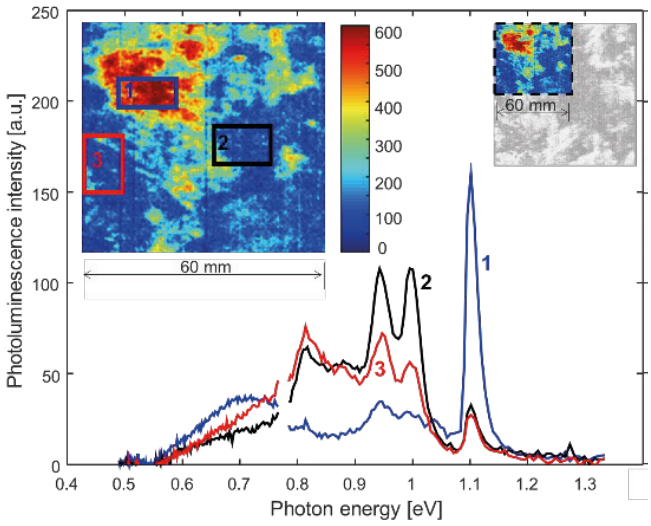
The third task silicon-based Building-integrated PV (BIPV) solutions was set up to demonstrate the feasibility of using solar cells in buildings in a manner where they would have multiple roles, including functional roles as building elements. The goals of this task were:

1. **To develop a fundamental understanding of the link between measurable optical properties and the perceived visual appearance of solar modules**
2. **To develop methods to achieve the desired appearance, in particular colour, while maintaining as high efficiency as possible for solar modules.**

Due to changes in the consortium, and rapid development and adaptation of high efficiency solar cell architectures in the industry, research targeting conventional high efficiency silicon solar cell and module technology became less important for the user and research partners. Resources were therefore focused towards other topics. In WP3, most research was focused on novel, high risk/high reward concepts such as photon conversion, intermediate band absorbers and tandem solar cells that have the potential to exceed Shockley-Queisser limit. In addition, BIPV was an important topic. WP3 was initially headed by Kristin Bergum from UiO. Towards the end of the centre duration, professor Eduard Monakhov, also from UiO, took over this activity.

Silicon wafers for high efficiency solar cells

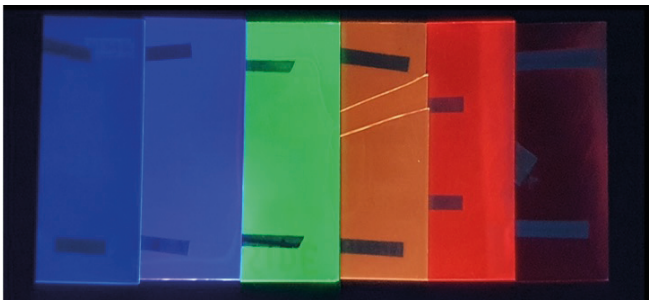
One early achievement in WP3 was the development of hyperspectral photoluminescence imaging for silicon wafers by researchers at NMBU, supported by IFE. A method for carrier lifetime analysis was refined and utilised to study the dominant active defects in silicon wafers. This is particularly important for studies of degradation mechanisms such as light-induced degradation (LID) and light and elevated temperature-induced degradation (LeTID). A successful collaboration between IFE, NMBU and the leading PV research institute in Europe, Fraunhofer ISE yielded excellent scientific results that were published. This method enabled the evaluation of the impact of the process steps involved in solar cell production, such as phosphorous diffusion and high temperature contact firing with the presence of H-rich surface layers, on the wafer material quality and solar cell efficiency. Thorbjørn Mehl from NMBU successfully defended his PhD thesis in this field, a work that resulted in several publications.



Hyperspectral photoluminescence imaging of a Si wafer. The red color indicates areas with short life time, i.e., high concentration of defects. The curves 1, 2, and 3 show the spectra recorded from the corresponding areas on the wafer. (Source: NMBU).

Beyond 25% efficiency crystalline silicon solar cells

One of the approaches to exceed the Shockley-Queisser limit is to manipulate the sunlight incident on the solar cell. This can be done by converting each energetic ultraviolet (UV) photon to two red or infrared photons, each of which can subsequently be collected by the solar cell and converted to electricity, contributing to with higher currents, and therefore a higher efficiency. Researchers at UiO demonstrated that such conversion materials can be deposited on both solar cells and modules. Below, we show different films that convert UV light to visible light with different colors. For the use in silicon solar cells, the conversion to red light is preferred. Future research will be focused on increasing the quantum efficiency of the photon energy conversion process.



Demonstration of conversion from UV-light to visible light of different colors. (Source: UiO)

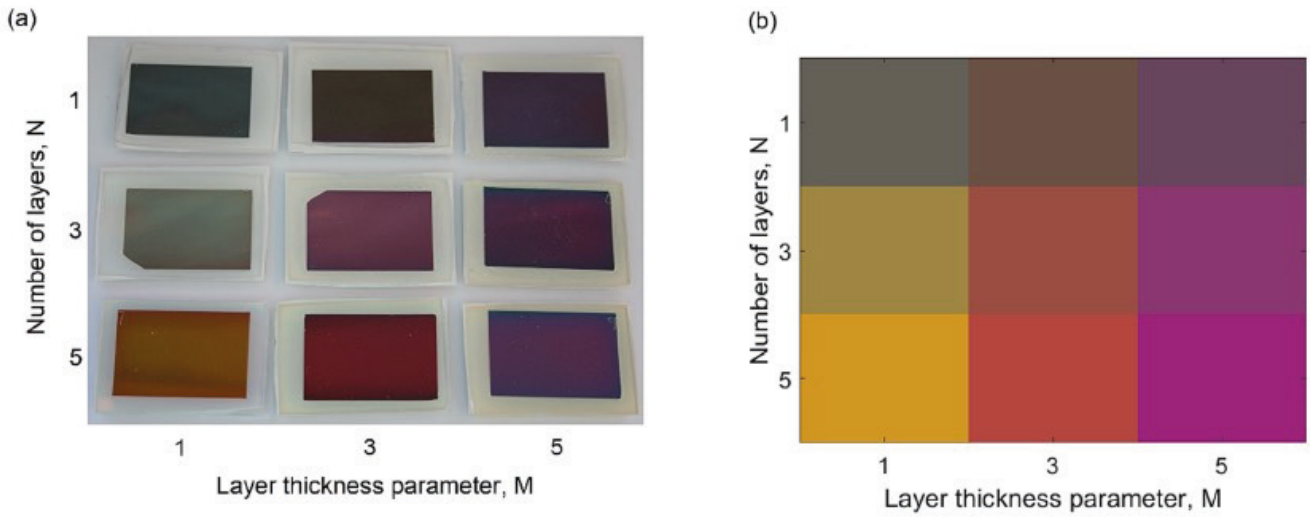
Another approach for exceeding the Shockley-Queisser limit is to synthesise a semiconductor material with multiple band gaps by modifying the chemical composition to induce a so-called intermediate band in the intrinsic band gap of a semiconductor. Researchers at NTNU have synthesised several intermediate-band materials based on Si or titanium oxide (TiO2), where the intermediate band was induced by adding silver (Ag), tungsten (W), chromium (Cr) or nitrogen (N). These exploratory studies aimed at developing materials with properties suitable for practical applications. Hogne Lysne from NTNU performed important work in this activity, which resulted in several publications, and successfully defended his PhD.

The most promising and mature approach to achieve efficiencies beyond the Shockley-Queisser limit today is the tandem or multi-junction solar cell, where two or more cells optimised for different regions of solar spectrum are combined into one solar cell. Due to the proliferation of silicon solar cells, there is a large global push to develop silicon-based tandem solar cells. In terms of efficiency, the most successful technology is based on the hybrid organic-inorganic halide perovskites (HOIPs). However, the commercial adoption of silicon-based tandem cells has been repeatedly postponed due to challenges including the presence of lead (Pb) and instability and degradation of the cells under the light and in moisture. Within WP3, researchers at NMBU have developed a method for probing and mapping the band gap in perovskite materials based on hyperspectral photoluminescence spectroscopy. PhD candidate Ivar Loland Råheim from NMBU performs his work in this field.

An alternative approach for Si-based tandem solar cells, promoted by researchers at UiO, is to use fundamentally stable, fully inorganic materials based on common and non-toxic elements. One of such materials is cuprous oxide (Cu2O). In FME SUSOLTECH, Cu2O films were synthesised by magnetron sputtering and characterised to determine critical parameters related to the use in solar cells. In the figure below, the yellow-brownish appearance of the films shows how the Cu2O captures the UV and blue parts of the spectrum while transmission the remainder towards an underlying cell, crucial for use in a tandem cell. At UiO, Martin Nyborg successfully defended his PhD thesis on tandem solar cells made from this material system, work that resulted in several publications.

At the time of writing, the electronic properties are so far not satisfactory for fabrication of a solar cell. Further research is necessary for improving the electronic properties of this material.

Cu2O thin film. (Source: UiO)



Visual appearance of the multilayer modules after the fabrication (a) and the expected colours from the numerical simulations (b). (Source: IFE)

Silicon-based Building-integrated PV (BIPV) solutions

Much of the activity on BIPV in FME SUSOLTECH was based on researchers from SINTEF and IFE with capabilities to model, synthesise and characterise BIPV materials working in close collaboration with the architects at NTNU. Several user partners also had a strong focus on BIPV, particularly Glass- og Fasadeforeningen, Oslobygg and Solenergi FUSen. In FME SUSOLTECH an optical modelling framework was developed which enabled simulating both the colour perception and the efficiency of coloured Si solar cell modules. This was used to design and fabricate coloured modules based on optical interference from thin film multilayers. Such layers were deposited on the module glass in order to achieve saturated and bright colours while maintaining relatively high power conversion efficiency for the solar cell module. The figure shows selected colours achieved of the multilayer modules besides the theoretically predicted colours. An important characteristic of interference colours is that the reflected colour may depend rather strongly on the observation angle. This effect can be reduced by using glass with a surface topography.

For wide-spread deployment, one key function needed for BIPV is architectural integration into the urban environment. In FME SUSOLTECH, researchers at NTNU proposed several strategies that account for building volume and architectural composition, size of PV modules, colour pallet of the buildings, and colour harmonisation via colour pairing, pixelation, colour mixing and lightness gradation. Practical suggestions for renovation of different urban areas were put forward, as exemplified in the figure below. Within WP3, Chanying Xiang from NTNU successfully defended his PhD thesis addressing architectural integration of BIPV.

End use and impact

Introduction

The activity targeting end use and impact was covered in FME SUSOLTECH's WP4 and originally consisted of three separate tasks: Strengthening the solar cell industry, Sustainability and Field performance of PV modules. The first task included both innovation research at UiO and targeted development and dissemination from the centre. The second task supported activities addressing a key strength of the Norwegian PV manufacturing industry, namely the low carbon footprint associated with their production of silicon materials. The third task represented a new, national collaboration which was anticipated to grow substantially in importance throughout FME SUSOLTECH. Field performance of PV modules has been the largest and longest task in WP4, with activity from all research partners. This task has developed new methods for estimating the degradation of PV modules which have been put to use on Norwegian PV plants. Here, the degradation in Nordic conditions has been estimated to be around 0.3 %/yr. Research addressing the performance of PV systems in Nordic conditions has also been an important topic, focusing on how moisture ingress drives solar cell degradation and the impact that spectral irradiance has on performance. The task has supported the establishment and expansion of PV test facilities in Grimstad, Kjeller, Ås, and Trondheim with research-grade monitoring of weather and PV performance.

Within PV performance and degradation, two PhD candidates have successfully defended their PhD theses in FME SUSOLTECH. Basant Raj Paudyal defended his thesis related to the assessment of PV performance in Nordic

conditions at UiA. Also at UiA, Oscar Kwame Segbefia defended his thesis investigation the role of moisture ingress in solar cell degradation. WP4 also included research on methods for fault detection of PV power plants based on imaging, which will be described below. Importantly, WP4 also enabled early activities in dual use of areas in an agricultural setting (agri-PV), a field which has since caused widespread interest and adoption,

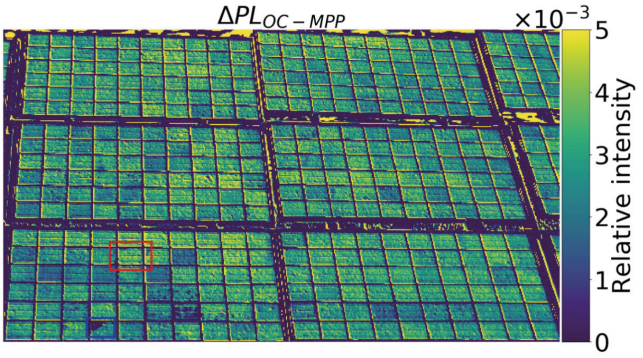
WP4 was headed by Heine Nygard Riise from IFE.

Strengthening the solar cell industry

In this task, innovation researchers at UiO delivered insightful analysis of the strengths and weaknesses of the Norwegian PV industry, including barriers for innovation, summarised in the report "The Norwegian Solar Energy Innovation System". To support the development of a broader domestic PV industry, FME SUSOLTECH led and co-authored a roadmap for the Norwegian PV industry, "Veikart for den norske solkraftbransjen mot 2030", and also supported the development of a report addressing the impact of PV power production in Norway, "Verdiskaping og ringvirkninger av solkraftutbygging i Norge mot 2040". Both of these were developed in close collaboration with the Norwegian Solar Energy Cluster (Solenergiklyngen).

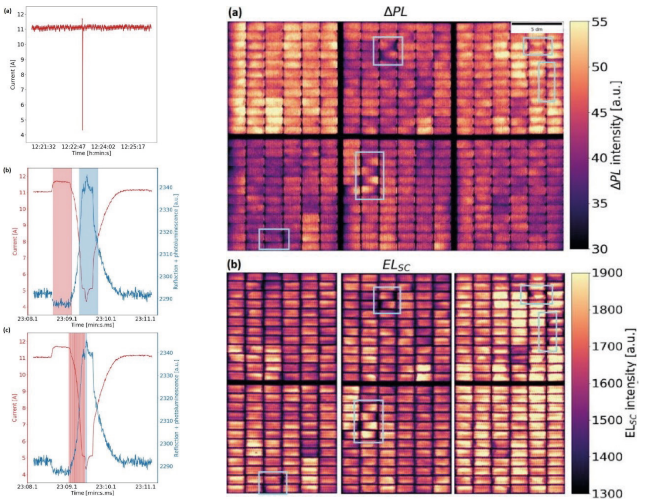
Fault detection and diagnostics by photoluminescence imaging

A particular highlight of the research in WP4 was the excellent work from NMBU and PhD candidate Marija Vukovic on the development of new and innovative ways supporting fault detection and diagnostics in PV modules by the use of outdoor imaging of PV modules with photoluminescence (PL). The method gives valuable information about module degradation which cannot be detected with, for example, conventional colour images. When collecting PL images, natural sunlight reflected off the module surfaces is a significant source of noise. Removing sunlight reflection requires imaging the PV modules in high PL conditions (open circuit conditions) and low PL conditions (short circuit conditions), to reveal PL response of individual cells. Acquiring images under both conditions while considering sunlight conditions and image throughput was a daunting task that was the focus of Marija's PhD work. Marija's efforts included both wireless communication between the inverter and the camera and exploiting the intrinsic current sweep of the inverter. In the first approach the wireless communication switched the inverter from open circuit to short circuit in a short time frame. A resulting image can be seen in the figure below, where higher intensity is associated with from photoactive defects in the solar cells.



PL image of a full PV string using NMBU-developed imaging methodology. (Source: M. Vukovic et al., AIP Conference Proceedings (2022))

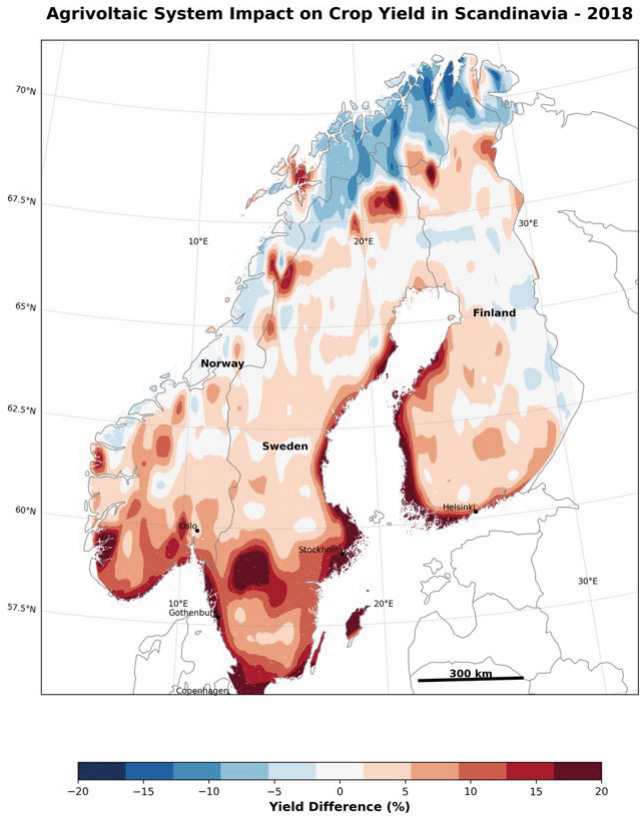
A second methodology Marija investigated did not require changing the operation of the inverter or the PV modules. This was seen as highly attractive since it does not necessitate taking parts of a PV park offline during an imaging campaign. This methodology is based on inverter performing current-voltage sweeps, something inverters commonly perform to ensure they are operating at the maximum power point. During such a sweep, the electrical environment switches from the maximum power point to open circuit conditions and back in a matter of seconds. By acquiring and analyzing multiple PL images during this time, the PL signal in high PL conditions and low PL conditions can be extracted. The contribution was published in Applied Physics Letters and chosen as a featured article. The figure below shows a resulting image of the procedure. Applying this procedure, Marija and her colleagues were able to show that PL imaging is not limited to being conducted only under direct sunlight. It can be carried through under as little as 40 W/m2 measured during a heavily clouded, winter day. The PL images obtained in this way give additional information about modules' damage. Marija's important contributions are summarised in her PhD thesis and a recent review article.



Left: Current of the inverter during an IV curve sweep. The blue and red areas mark the selected images resulting in a PL image. Right: PL image of a string consisting of three bifacial modules connected in series (a) and three ELSC images of the modules (b). (Source: M. Vukovic et al., Applied Physics Letters (2022))

Agri-PV and ecovoltaics

Agrivoltaics (Agri-PV) and ecovoltaics are two rapidly expanding fields of research and development. To capture this important trend early, WP4 initiated activity within this field in 2022. IFE hired the PhD candidate Erlend Hustad Honningdalsnes to investigate how PV plants can be made more sustainable by understanding how an area can be used for both energy production and other purposes, such as agriculture or eco-system services. Erlend has made significant contributions to the field. Already in his MSc thesis at NTNU, he developed an algorithm for autonomous optimisation of agri-PV systems in Norway. During his PhD, Erlend has focused on microclimate modelling and microclimate monitoring of such systems. In his most recent papers, he has demonstrated that the choice of ray-tracing tools can have large impacts on the efficiency of modelling agri-PV plants and that agrivoltaics systems can actually give positive impacts to the agricultural sector. The last point is exemplified in the figure below where it can be seen that vertical PV panels placed on Norwegian agricultural land under the right circumstances can boost agricultural yield. The boost stems from reduction of wind speeds between the vertical panels, reducing the evaporation from the soil making it less vulnerable to drought. This activity has been able to attract more funding among others through the competence project "Envisol".



Agricultural yield if vertical agri-PV parks were mounted on Norwegian fields. The yield boost stems from wind speed reductions inside the PV park. (Source: IFE)

The agri-PV activity has also led to significant infrastructure investments. SINTEF and NTNU has established an agri-PV pilot plant in collaboration with Skjetlein High School, ANEO, and Grønt Hjerte. This is a 50 kWp plant consisting of four rows of double height, vertical bifacial solar panels, which is instrumented with monitoring equipment for light and microclimate. An image of the pilot is seen below.

SINTEF researcher Gaute Stokkan in front of the Skjetlein agri-PV pilot

NMBU has recently established a similar system in Ås with three rows of vertical panels, and significant monitoring equipment. The two systems at NMBU and Skjetlein will be used to demonstrate the feasibility of supporting agricultural activity and power production through establishing agri-PV plants in Norway. The systems are set up for detailed experiments within both energy and agriculture and have already spawned new research activity through a new competence project, "Soldeling i Landbruket". The new FME center on PV research, FME SOLAR, also benefits from these infrastructures and we expect that the test sites will produce excellent research and support collaboration between Norwegian research institutions in years to come!

5. Selected success stories from the FME SUSOLTECH user partners

An important role of FME SUSOLTECH has been to support innovation and value creation among its user partners. The centre has itself been directly responsible for producing commercial results. A range of improved products, new processes and services have been developed by several partners. To enable larger impact in this context, the main underlying idea for supporting innovation and value creation in FME SUSOLTECH has been to develop a knowledge base and new methods which subsequently have become an important basis for the development of innovation and industry projects, and to build the required competence, capacity and infrastructure to enable the partners to efficiently lead, perform and exploit the results generated in these projects in their daily business. In the following, we focus on four selected success stories from the FME SUSOLTECH user partners which in different ways have benefited from the activities in the centre.

High quality monocrystalline silicon production and improved crucible materials

A major strategic decision made during the initial development of the FME SUSOLTECH research activities was to maintain a strong focus on the already quite mature manufacturing value chain for silicon-based solar cells and modules. This strategy was shared by both the active domestic companies in this part of the value chain, as well as the research partners, who held leading competence and research infrastructure in this important field. At the time of writing, silicon-based technologies have increased their market share to ~98%, a powerful indication of the benefits of this class of technologies.

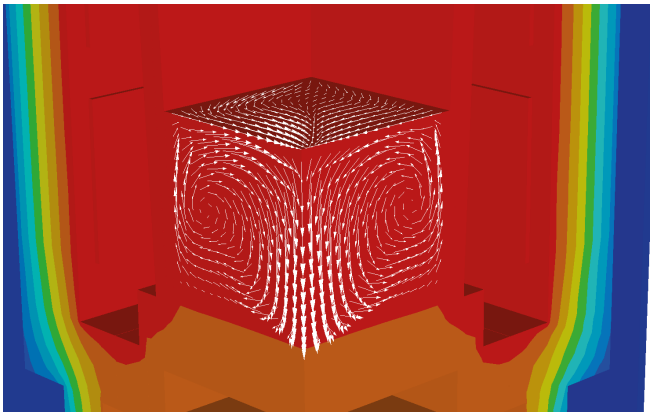
The Norwegian user partners Norsun, Norwegian Crystals and The Quartz Corp (TQC) were supported by the German supplier of manufacturing tools PVA Tepla to develop an activity supporting future innovation and value creation in this field. At the start of activities in 2017, the Norwegian companies competed internationally and played key roles supporting European manufacturing. The research and development performed within FME SUSOLTECH was important in shaping innovation projects and industrial activities in these companies.

Due to intense competition and price pressure, particularly from China, most European and subsequently Norwegian manufacturing capacity of silicon materials, ingots, wafers and solar cells was shut down. We would like to stress that the Norwegian closures happened in spite of extreme cost-reductions combined with a high material quality and products leading in sustainability parameters offered by the Norwegian companies. The exception is TQC, who have successfully identified opportunities in the global value chains for their high purity quartz materials.

In spite of the challenges in later years, these companies have had a large impact. One good example is Norsun. From 2017 until the closure of their Norwegian factory in Årdal in 2024, the company produced wafers used to fabricate PV modules with a nominal capacity of ~2.5 GWp. This resulted in a turnover of ~3 BNOK and Norsun securing a unique position in the European industrial landscape for the company. Norsun was also able to develop and demonstrate extremely environmentally friendly production. The close to 12 TWh hitherto produced using Norsun wafers have contributed to a reduction in CO2 emissions from power production of ~3.5 million ton CO2e. Over their full lifetime, more than twice as much power will have been produced by these PV modules, with a corresponding further reduction in CO2 emissions.

TQC has maintained its important foothold as a supplier of highly pure quartz materials to the international PV industry. Their manufacturing site in Drag remains an important part of their operations, and is continuously upgraded. In Drag, quartz materials are collected and refined before being shipped off to consumers around the globe.

The inclusion of Norsun and TQC in FME SUSOLTECH, particularly in WP2, enabled unique, full-scale experiments related to both crucibles and crucible materials and machine-learning supported control of manufacturing tools.



Modelling of Si production processes has been an important activity in FME SUSOLTECH

High quality recycled Si materials

Production of silicon feedstock relies on energy demanding processes. To overcome limitations associated with the main production technology today: silane-based silicon feedstock production based on Siemens reactors, several Norwegian companies pursued separate proprietary process routes, two of which were addressed in FME SUSOLTECH's WP1.

A particular stronghold in FME SUSOLTECH was metallurgical production of silicon feedstock, a process that was brought to market and full-scale production by REC Solar Norway. The resulting material was documented to be among the most sustainable feedstock materials in the world and was successfully used in industrial manufacturing of high efficiency silicon solar cells and modules.

Initially, this process was based on in-house processing of silicon products that were subsequently further refined. REC Solar Norway recognised the unique opportunity of their process to include or even fully rely on recycled silicon materials. Full-scale production of high purity silicon feedstock based on recycled silicon kerf materials was subsequently demonstrated. Unfortunately, due to intense competition and price pressure, REC Solar Norway shut down their activities in Norway in 2024.

Silicon

At the start of FME SUSOLTECH, the company Dynatec was also involved in WP1, with another unique silicon feedstock production technology based on a chemical production of silicon in a centrifugal reactor utilizing silane gas. Although high throughput production of highly pure silicon materials was successfully demonstrated, the company chose to pursue attractive commercial opportunities in the market for battery materials, and the technology and competence from this endeavour has been continued in the company Cenate.

Building-applied and building-integrated PV power plants
Although ground-mounted PV power plants make up the largest volume of new PV installations, there is also a tremendous volume of rooftop systems installed every year. Approximately 1/3 of the accumulated global PV capacity 2.2 TWp installed to date are rooftop systems. In Norway, the share of rooftop systems is significantly larger and makes up the by far largest part of all installations. Building applied (BAPV) and building-integrated (BIPV) PV power plants are anticipated to continue to play a major role in the targeted growth in the use of PV in Norway. To support future growth, such installations must be highly performing, durable and cost-competitive. For PV in buildings, full integration of PV into the built environment represents a hitherto vastly underexploited opportunity. With the right solutions, synergistic use of materials and components can be combined with synergistic installation processes to reduce both costs and environmental footprint.

Several user partners in FME SUSOLTECH have been very active in developing, installing and operating BAPV and BIPV systems in Norway. One good example are the architects in CODE who have developed several winning projects fully integrating PV into the building environment. One recent, impressive example is the residential building Oen, which is currently under construction at Ammerud in Oslo. Another good example is FUSen Solenergi, one of the most experienced installers of PV systems in Norway. This company has installed a large share of the larger rooftop systems on commercial and industrial (C&I) rooftops in Norway. In addition, the company has developed and installed many of the most impressive BIPV projects in Norway, including Oljedirektoratet in Stavanger and the award-winning Voldsløkka Skole. Another example is Oslobygg, who as a public developer and owner of a large volume of buildings in the municipality of Oslo have supported the development of and currently own and operate a large number of BIPV projects.

All of these user partners have made important contributions to and benefited from the research activities related to BIPV in WP3 and PV systems in WP4 of FME SUSOLTECH.

Dissemination to society and broader user groups
In FME SUSOLTECH, two user partners played a particularly important role in supporting the centre management in developing content and facilitating dissemination of relevant results and insights from the centre activities to broader target audiences.

The collaboration with the Norwegian Solar Energy Cluster (Solenergiklyngen) was a particular highlight. In the early years, FME SUSOLTECH arranged Solar Industry Forum meetings to facilitate dissemination and discussion with user partners and target groups. This activity become much more powerful when FME SUSOLTECH and Solenergiklyngen joined forces in hosting target group-specific events.

In addition, FME SUSOLTECH and the Solar Energy Cluster collaborated closely on the development and subsequent dissemination a roadmap for the Norwegian PV industry ("Veikart for den norske solbransjen mot 2030"), which reached a broad audience and has impacted broader strategy development related to both energy and industry in Norway. FME SUSOLTECH and the Solar Energy Cluster also collaborated on developing the report "Verdiskaping og ringvirkninger av solkraftutbygging i Norge mot 2040", which was written by Thema Consulting and demonstrated the potential for value creation resulting from installations of PV in Norway.

FME SUSOLTECH also collaborated with the industry and employer organisation Glass and Façade Association of Norway, which represents many of the companies in the Norwegian construction sector. Their architecture magazine, Glass & Fasade, regularly featured articles

Oen, Oljedirektoratet, Dronning Ingrids Hage-panelene

from FME SUSOLTECH. 4.000 copies of the magazine are distributed four times yearly. The articles were also published on their online platform, glassogfasade.no.

Veikartforside, Themaforside, Glass og fasadeforside(r)

6. Education and researcher training

Education and training of candidates at MSc, PhD and postdoctoral levels with relevant competence for the PV industry and research community was an important activity in FME SUSOLTECH. The growing, domestic and global PV community required increased access to experts. The four university partners in FME SUSOLTECH, NMBU, NTNU, UiA and UiO, played crucial roles in this context. FME SUSOLTECH included 15 PhD and 11 postdoctoral positions funded either fully or partly through the FME SUSOLTECH grant or funded through in-kind contributions from the research partners. FME SUSOLTECH also supported the education of 91 MSc students who performed their thesis work within the centre. The full list of candidates performing their thesis work in FME SUSOLTECH is shown in Appendix 2. The education of 91 MSc candidates far exceeded the initial target of 40 and is the result of a strong interest in the field demonstrated by the research partners, students and industry and society at large.

To better understand the need and role of these candidates, FME SUSOLTECH mapped the first position held by all candidates after they had finalised their work in the centre. Out of the 11 finished post.doc candidates at the time of the analysis, 7 were found in industry, the remainder in research and education. 4 PhD candidates were still working towards their thesis at the time of the analysis. Out of the 11 PhD candidates that had already finished, 7 were found in industry, while 4 had continued their careers in research with a post.doc position. Out of the 91 finished MSc candidates at the time of the analysis, 57 were found in industry and 14 in PhD positions. For the remainder, the information was not found.

7. Communication and dissemination

Renewable energy is a topic that is of very broad interest and the subject of much public debate. Among the renewable energy technologies, PV technology is emerging as a winning technology globally, and record annual installation rates are becoming the norm globally. Communication and dissemination of knowledge was an important activity in FME SUSOLTECH which to a large extent followed four separate approaches based on intended target groups. In addition to these approaches, the centre established and continously updated its website: www.susoltech.no.

Internal sharing and discussion of results

First and foremost, internal sharing and discussion of results among the partners was important, both to facilitate discussion, to keep all partners updated on the scientific production of FME SUSOLTECH, to develop and maintain inter-institutional collaboration and to support the generation of new research, development and innovation activities based on the centre results. In this context, the work package meetings and the annual meeting of FME SUSOLTECH were particularly important.

Communication to the broader PV community

Secondly, communication to the broader PV community of selected scientific results through articles in international scientific journals and at national and international research conferences was important. FME SUSOLTECH was a highly productive research centre in this regard. The full list of scientific publications is shown in Appendix 3.

Dissemination supporting a growing domestic PV community

Thirdly, supporting a growing domestic PV community was prioritised. Updating the broader industry was a goal from the start, and the main motivation for establishing the Solar Industry Forum meetings. Over the years, an even wider audience was reached through the collaboration between FME SUSOLTECH and the Norwegian Solar Energy Cluster (Solenergiklyngen). Together, the two arranged meetings and conferences. The centre also supported contributions in various popular scientific, trade and public media. This included regular features in the magazine Glass og Fasade, an important communications channel in the Norwegian building sector. The full list of these presentations is also found in Appendix 3.

Dissemination targeting societal impact in Norway and Europe

Finally, societal impact in both Norway and Europe was important for FME SUSOLTECH to increase the general awareness of the rapid developments in the field of PV, and their impact in industry and society, as well as the related opportunities and challenges associated with this development. A particular emphasis was put on communicating important global trends, including the tremendous growth in installed PV capacity worldwide, and the corresponding opportunities for value creation. Supporting innovative industrial value chains in PV in both Norway and Europe was deemed particularly important. To this end, center colleagues gave lectures and presentations for various audiences, as well as participated in meetings and processes, including lectures for policymakers and a broader energy industry, and important strategy processes like the Norwegian Energi21, the European Energy Research Alliance and the European Solar PV Industry Association (ESIA).

FME SUSOLTECH together with the Solar Energy Cluster also produced several important reports to demonstrate the increasingly important role of PV for industrialisation and value creating also in Norway. Chief among these was the Roadmap for the Norwegian PV industry towards 2030. The Roadmap attracted broad interest in both media, the political community and various organisations. The Solar Energy Cluster joined FME SUSOLTECH as a partner in 2021 to facilitate this type of collaboration.

8. International cooperation

International collaboration is key aspect of research and development, and of high importance to FME SUSOLTECH in its daily work. The consortium was supported by one international industry partner, PVA Tepla, who filled an important gap in competency and capacity related to manufacturing of process equipment for silicon production. In the following, the broader international cooperation will be divided into four distinct parts: research collaboration, exchange, supporting European manufacturing value chains and generation of international projects.

International research collaboration

International research collaboration was important in many of the research tasks in the centre. This is evidenced by the many international co-authorships in the list of produced papers in Appendix 3, including co-authors from several of the leading research groups in the world. In addition, researchers in FME SUSOLTECH were broadly active in international collaborations, several times in leading roles. Important for a for international collaboration included the collaborative Performance and Reliability of Photovoltaic Systems: Evaluations of Large-Scale Monitoring Data (PEARL PV), the International Energy Agency PV Power Systems programme (IEA-PVPS), and the collaborative PV Camper focussing on climate zone dependent performance and reliability of PV power plants.

Candidate exchange

Exchange of candidates is an important aspect of researcher training. One important aspect of this was the shorter and longer exchanges of candidates and personnel to and from the FME SUSOLTECH partners. Another important aspect was formalised international collaboration in the field. FME SUSOLTECH was involved in an initiative to establish a Nordic meeting place for PhD candidates and early stage researchers in PV. This latter resulted in a first such meeting hosted by the University of Oslo where candidates from the Swedish PV research centre SOLVE visited PhD candidates from FME SUSOLTECH and surrounding projects. This collaboration is now extended with the Danish University of Technology (DTU) and is a formal collaboration within the new Norwegian PV research centre FME SOLAR.

Supporting the establishment of European manufacturing value chains in PV

Supporting the establishment of European manufacturing value chains in PV involving several of the FME SUSOLTECH user partners was an important goal. Both research and user partners from FME SUSOLTECH were highly active in this regard and participated and sometimes led important processes in this context, including processes within the European Solar Industry Alliance (ESIA), the European Solar Manufacturing Council (ESMC), Solar Power Europe (SPE) and the European Energy Research Alliance (EERA). In this context, the collaboration with the Norwegian Solar Energy

Cluster (Solenergiklyngen) was instrumental. A big effort was devoted to supporting Norwegian participation in a European IPCEI initiative, an effort that was unfortunately not successful.

Generation of international research projects

FME SUSOLTECH was an important support for the partners with respect to developing EU projects. Based on a strategic building of competence and capacity, the FME SUSOLTECH research partners successfully entered and won projects within Horizon 2020 and Horizon Europe. Particularly important in this context are projects related to Building-Integrated PV and recycling. Within recycling, IFE coordinates the EU project RETRIEVE and SINTEF coordinates the EU project QUASAR. A list of relevant projects in this context are listed below. The research groups and companies within FME SUSOLTECH are involved in and also coordinate a substantially longer list of EU projects where the ties to FME SUSOLTECH are less important.

- **SUPER PV (GA no: 792245)**
- **PV Adept (GA no: 818342)**
- **BE-SMART (GA no: 818009)**
- **Icarus (GA no: 958365)**
- **RETRIEVE (GA no: 101122332)**
- **QUASAR (GA no: 101122298)**
- **Circular manufacturing 5.0 (GA no: 101178331)**

9. Effects of FME SUSOLTECH

The FME programme was launched in 2009 and is one of the most important instruments in the Research Council of Norway (RCN) portfolio targeting research related to environment-friendly energy. The overall objective of the programme is to help to solve key challenges in the energy sector, generate solutions for the low-emission society and enhance the innovation capacity of the business sector. The programme is also expected to strengthen technology transfer, internationalisation and researcher training. FME SUSOLTECH was subjected to an external evaluation by RCN after its first five years of operation and was found to be largely on track in this regard. FME SUSOLTECH has had a broad range of effects in line with the overarching goal of the FME-programme, as will be discussed below.

Effects for the research partners

FME SUSOLTECH has been a very important centre for its research partners. The centre has directly funded activities of high strategic relevance supported developing their competence and capacity, and supported use and development of important physical and digital research infrastructure. The long-term funding and collaboration has enabled the centre to both impact the strategy of the research partners in the field of PV, and fostered the national collaboration, which is now continuing within FME SOLAR. It has also facilitated establishment and maintenance of international collaboration within PV, and also supported visibility.

The capacity and competence has again supported the research partner's development of and inclusion in multiple national and international research and innovation projects. FME collaboration within PV has been particularly important for their success in Horizon 2020 and Horizon Europe, as described in the previous section. In Appendix 4, a list of projects which have built on capacity, competence and/or infrastructure developed within FME SUSOLTECH is shown. In addition to maintaining a strong research activity in the field of PV materials, FME SUSOLTECH through the inclusion of WP4 on End use and impact opened up a new field of national collaboration within PV systems. This has since become a large activity in Norway both in research and industry and is the core of the newly established research centre FME SOLAR.

Candidates educated within FME SUSOLTECH have been also important for building the research partners. This both relates to PV-specific backgrounds, as well as a more generic expertise in materials science has also been very important when building new research and development activities in fields such as battery technology and recycling.

Effects for the host institution

In addition to sharing the benefits listed above, IFE has seen additional effect by acting as the host institution of FME SUSOLTECH. Firstly, the capacity and experience related to the direction and hosting of large, multi-partner projects has been substantially strengthened. Hosting a successful research centre in a field of high international development and industry growth has also given IFE much visibility. Additionally, the support of the new activity on PV power plants in WP4 provided a safety net for a growing activity at a fragile, early stage. Over the course of FME SUSOLTECH, PV Power Systems has emerged as a large and growing activity and, eventually as a separate Department at IFE, which has become highly successful internationally and an important support for innovation activities in a rapidly growing field in Norway. IFE has also had much success in attracting EU funds.

Effects for the user partners and the broader PV community

FME SUSOLTECH has been important for innovation and value creation among its user partners and the broader domestic PV community in three distinct ways. The centre has itself been directly responsible for producing commercial results, as has been shown in the overall table of results in a previous section. We would like to stress that these concrete improved products, new processes and services, although very positive and a natural consequence of the inclusion of a substantial user partner activity, is not been the main strategy for innovation in FME SUSOLTECH. Rather, the main idea has been to more broadly support innovation and value creation in two other ways, which together represent a substantially more suitable and efficient approach. It is also more in line with the day-to-day running of a long-term collaborative centre involving multiple competing companies. FME SUSOLTECH has been used to develop a knowledge base and new methods which have become an important basis for the development of innovation and industry projects, as well as to build the required competence, capacity and infrastructure to enable the user and research partners to efficiently lead, perform the required work in and harvest from such projects.

Based on activities in FME SUSOLTECH, the user partners have then developed projects and activities with substantial concrete effects on a broad set of factors including power production, industrialisation, exports and value creation and sustainability. The involvement in FME SUSOLTECH has also supported strong collaboration both between user and research partners, as well as among the user partners themselves.

Effects for a broader domestic PV community and for society at large

FME SUSOLTECH has strived to generate and subsequently publish new, relevant knowledge and data, thereby supporting a broader, international scientific and industrial development. The building of competence, capacity and infrastructure has had broad impact, particularly in the field of PV power systems. The access to qualified personnel has also been important. Many of the candidates educated within FME SUSOLTECH are found in industry in Norway and abroad today.

Again, we would like to mention the Roadmap, which also has had substantial impact in Norway and helped raising the awareness of the large opportunities associated with the rapid deployment of PV globally, as well as the goals for and expectations to a domestic PV industry.

10. Final remarks

At the time of writing, the last activities in FME SUSOLTECH are being concluded. We are immensely grateful for the invaluable funding from both the Research Council of Norway and our research and user partners, and very proud of the results we have been able to deliver together. The centre partners who are still active in PV are well placed to continue to grow their activities in this important field. In this context, we would like to make a few final remarks.

- **The global solar cell industry is both larger and growing faster than ever, making enormous contributions to the development of a sustainable global energy system every year. The large opportunities and challenges facing this industry ahead is a call for research, development and innovation of new solutions to support both production, deployment, integration and sustainability. PV is increasingly relevant both in Norway and internationally.**
- **FME SUSOLTECH maintained a strong focus on silicon-based solar cell technologies, with a particular strength upstream in the production of silicon feedstock, ingots and wafers. These technologies remain mostly unchallenged in the global industry today. In spite of excellence, a large part of this industry in Europe and Norway was unable to cope with the extreme price pressure from particularly China. If Europe and Norway wants to re-establish manufacturing value chains, competence and capacity remains available among others at the research partners of FME SUSOLTECH and can play an important role.**
- **FME SUSOLTECH established a new, national collaboration on PV systems. This has been an important support of a broader emergence of PV systems research and innovation activities and projects in Norway. This part of the domestic PV industry makes up the largest volume of activity and also an increasing share of the ongoing research, development and innovation projects.**

Many of the activities from FME SUSOLTECH will be continued. There is a substantial volume of surrounding projects with RCN or EU funding, as shown in Appendix 4. We are also extremely grateful to be able to continue and extend the national collaboration in PV research through the newly established Norwegian PV research centre (FME SOLAR), which commenced its operations last year and will be in operation until 2032.

Appendix 1

Funding & Costs FME SUSOLTECH 2017-2025

Funding (kNOK)

Activity/Item	RCN	Host institution (IFE)	SINTEF	NMBU	NTNU	UIA	UiO	Bondelaget	Code	Dynatec	REC Solar Norway
WP 1		1,615	1,773		4,314		320			2,722	1,812
WP 2		16,941	19,444	584	6,338		6,029				1,394
WP 3		12,932	1,667		1,963		7,356				202
WP 4		14,020	4,904	9,372	52	1,912	1,291	414	2,503		2,974
Networking		67									
Cash contribution	113,839									600	1,300
Equipment		1,468			2,473					186	
Management		850	301		492						
Sum	**113,839**	**47,893**	**28,089**	**9,956**	**15,632**	**1,912**	**14,996**	**414**	**2,503**	**3,508**	**7,682**

Funding (kNOK) (continues)

Activity/Item	FUSen	Glass og Fasade-foreningen	Norsun	Norwegian Crystals	The Quartz Corp	Equinor	Solenergi-klyngen	Steuler Solar	PVA Tapla	Oslobygg KF	Total
WP 1											**12,556**
WP 2			6,944	4,403	6,984			1,220	4,897		**75,178**
WP 3											**24,120**
WP 4	1,097	4,327				1,225	1,286			2,074	**47,450**
Networking											**67**
Cash contribution			1,100	600	1,500	4,400	200				**123,539**
Equipment								20			**4,147**
Management											**1,643**
Sum	**1,097**	**4,327**	**8,044**	**5,003**	**8,484**	**5,625**	**1,486**	**1,240**	**4,897**	**2,074**	**288,700**

Cost (kNOK)

Activity/Item	Host institution (IFE)	SINTEF	NMBU	NTNU	UIA	UiO	Bondelaget	Code	Dynatec	REC Solar Norway
WP 1	5,121	5,429		12,147		5,779			2,722	1,812
WP 2	25,165	30,245	584	11,594		12,034				1,394
WP 3	17,631	10,887		11,162		13,304				202
WP 4	23,852	7,864	11,018		3,258	4,422	414	2,503		2,974
Networking	1,651	238								
Equipment	2,673	896		2,923		2,309			186	
Management	15,546	1,574		1,674		1,035				
Sum	**91,639**	**57,134**	**11,601**	**39,500**	**3,258**	**38,882**	**414**	**2,503**	**2,908**	**6,382**

Cost (kNOK) (continues)

Activity/Item	FUSen	Glass og Fasade-foreningen	Norsun	Norwegian Crystals	The Quartz Corp	Equinor	Solenergi-klyngen	Steuler Solar	PVA Tapla	Oslobygg KF	Total
WP 1											**33,011**
WP 2			6,944	4,403	6,984			1,220	4,897		**105,464**
WP 3											**53,186**
WP 4	1,097	4,327				1,225	1,286			2,074	**66,314**
Networking											**1,889**
Equipment								20			**9,007**
Management											**19,829**
Sum	**1,097**	**4,327**	**6,944**	**4,403**	**6,984**	**1,225**	**1,286**	**1,240**	**4,897**	**2,074**	**288,700**

Postdocs, PhD and MSc degrees and key researchers

Senior researchers working in the Centre 2017-2025

Name	Institution	Periode
Arve Holt	IFE	2017-2025
Erik Stensrud Marstein	IFE	2017-2025
Gaute Otnes	IFE	2017-2025
Heine Nygard Riise	IFE	2017-2025
Josefine Selj	IFE	2017-2025
Junjie Zhu	IFE	2017-2025
Marie Syre Wiig	IFE	2017-2025
Rune Søndenå	IFE	2017-2025
Sean Erik Foss	IFE	2017-2023
Ørnulf Nordseth	IFE	2017-2025
Arne Røyset	SINTEF	2017-2025
Eivind Johannes Øvrelid	SINTEF/NTNU	2017-2025
Gaute Stokkan	SINTEF	2017-2025
Kai Tang	SINTEF	2017-2025
Mari Juel	SINTEF	2017-2025
Marit Synnøve S. Stange	SINTEF	2017-2025
Martin Bellmann	SINTEF	2017-2025
Mohammed Mhamdi	SINTEF	2017-2025
Ove Paulsen	SINTEF	2017-2020
Sylvain Gouttebroze	SINTEF	2017-2025
Tore Kolås	SINTEF	2017-2025
Arnkell Jonas Petersen	NMBU	2017-2025
Espen Olsen	NMBU	2017-2025
Ingunn Burud	NMBU	2017-2025
Barbara Matusiak	NTNU	2017-2025
Gabriella Tranell	NTNU	2017-2025
Jafar Safarian	NTNU	2017-2025
Marisa Di Sabatino	NTNU	2017-2025
Mari-Ann Einarsrud	NTNU	2017-2025
Randi Holmestad	NTNU	2017-2025
Turid Reenaas	NTNU	2017-2025
Anne Gerd Imenes	UiA	2017-2024
Tor Oskar Sætre	UiA	2017-2024
Tore Vehus	UiA	2024-2025
Rune Strandberg	UiA	2017-2024
Alexander Azarov	UiO	2017-2024
Edouard Monakhov	UiO	2017-2025
Jens Hanson	UiO	2017-2022
Kristin Bergum	UiO	2017-2025
Ola Nilsen	UiO	2017-2025

List of Postdocs, Candidates for PhD and MSc degrees during the full period of the centre

Postdoctoral researchers with financial support from the Centre budget

Name	M/F	Nationality	Scientific area	Years/period in the centre	Scientific topic	Main contact
Øyvind Sunde Sortland	M	Norwegian	High performance silicon ingots and wafers	17´07-19´12	Mono Si	Marisa Di Sabatino
Phillip Weiser	M	USA	High performance silicon ingots and wafers	17´08-21´09	Oxygen complexes in Si	Eduard Monakhov
Dimitra Chasanidou	F	Greek	End use and impact	18´05-22´09	Analysis of innovation system and end use	Jens Hanson
Mohammed Bilal	M	Pakistani	End use and impact	18´10-20´05	PV performance, field testing, monitoring, system analysis	Anne Gerd Imenes
Maria Tsouri	F	Greek	End use and impact	18´01-20´12	Social network analysis of PV R&D	Jens Hanson
Thomas V. Brakstad	M	Norwegian	High efficiency silicon solar cells and modules	21´09-23´07	Double oxide perovskites for intermediate band solar	Ingrid Hallsteinsen
Rania Hendawi	F	Jordan	High performance silicon ingots and wafers	22´01-24´05	Structure loss in Cz-Si	Marisa Di Sabatino

Postdoctoral researchers working on projects in the centre with financial support from other sources

Name	M/F	Nationality	Source of funding	Scientific area	Years/period in the centre	Scientific topic	Main contact
Ioannis Tsanakas	M	Greek	IFE	End use and impact	18´01-18´10	PV Performance, operations & maintenance	Josefine Selj
Guro Marie Wyller	F	Norwegian	IFE	High performance silicon ingots and wafers	19´11-21´02	Silicon ingots and wafers	Erik S. Marstein
Torbjørn Mehl	M	Norwegian	NMBU	High performance silicon ingots and wafers	19´03-22´10	LeTid in c-Si	Espen Olsen
Dounia Dahlioui	F	Moroccan	UiA	PV in Nordic conditions	24´01-26´01	Soiling and snow impact on Nordic PV	Anne Gerd Imenes

PhD candidates who have completed with financial support from the centre budget

Name	M/F	Nationality	Scientific area	Years/period in the centre	Thesis title	Main thesis Advisor
Thorbjørn Mehl	M	Norwegian	Spectral PL in silicon wafers	17´03-18´06	Hyperspectral Photoluminescence Imaging of Silicon Wafers and Solar Cells	Espen Olsen
Mengyi Zhu	M	Chinese	Silicon	17´08-20´08	Silicon purification by acid leaching and slag refining techniques	Jafar Safarian
Martin Nyborg	M	Norwegian	Oxide-based tandem cells	17´08-21´03	Dominant Defect Complexes in Cuprous Oxide	Eduard Monakhov
Hogne Lysne	M	Norwegian	Intermediate band cells	17´08-22´08	Design and fabrication of (Cr + N) co-doped TiO2 films with a continuous compositional spread	Turid Dory Reenaas
Marija Vukovic	F	Croatian	Spectral imaging of degradation in solar panels	18´08-22´05	Toward monitoring of photovoltaic power plants with photoluminescence imaging	Ingunn Burud
Chaniying Xiang	M	Chinese	BIPV architectural issues	18´09-22´03	Facade Integrated Photovoltaic-Architectural Methods in Urban Contexts	Barbara Matusiak
Azam Rasouli	F	Iranian	Silicon Production	19´09-22´08	Synthesis of Mg2Si and its use for Silane production	Jafar Safarian
Gabriela Warden	F	Polish	Sustainable silicon feedstock production	20´11-25´05	Quartz crucibles for Czochralski silicon production	Marisa Di Sabatino

PhD candidates who have completed with other financial support, but associated with the centre

Name	M/F	Nationality	Source of funding	Scientific area	Years in the centre	Thesis title	Main thesis Advisor
Arman Hoseinpur	M	Iranian	NTNU	Purification of solar grade silicon via the gas and vacuum refining processes	17´08-21´12	Vacuum and Gas Refining of Silicon for Solar Cell Applications	Jafar Safarian
Basant Raj Paudyal	M	Nepal	UiA	Monitoring the Performance and Degradation of Solar PV Systems	18´01-21´01	Assessment of PV Performance in Nordic Conditions	Anne Gerd Imenes
Oscar Kwame Segbefia	M	Ghana	UiA	Solar Cell Degradation: defect analysis and mitigation schemes	19´05-22´05	Solar cell degradation: the role of moisture ingress	Tor Oskar Sætre

PhD students with financial support from the centre budget who still are in the process of finishing studies

Name	M/F	Nationality	Scientific area	Years in the centre	Thesis topic	Main thesis Advisor
Ivar Loland Råheim	M	Norwegian	End use and impact	21´09-25´09	Spectral imaging of solar cell materials	Espen Olsen
Nicole Assmann	F	German	High performance silicon ingots and wafers	21´09-25´09	FT-IR of hydrogen in Silicon	Eduard Monakhov
Tinotenda Mubaiwa	M	Zimbabwe	Sustainable silicon feedstock production	22´08-25´10	Si-kerf recycling	Jafar Safarian
Erlend Hustad Honningdalsnes	M	Norwegian	End use and impact	22´12-25´11	Sustainable groundmounted PV	Heine Nygård Riise

MSc candidates with thesis related to the centre research agenda and an advisor from the centre staff

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Lisa Kvalbein	F	Norwegian	Study of thermal donors in Czochralski Si wafers	2017	Studie av termiske donorer i Czochralski silisium-skiver ved hyperspektral fotoluminescens	Espen Olsen
Mathias Strømmen	M	Norwegian	Cz crucible	2018	Liquinert quartz crucible Removal of OH groups in silica crucibles to reduce wetting between the crucible and the silicon melt	Marisa DiSabatino
Stine Linn Skjerven	F	Norwegian	Cz Si Structure loss	2018	Modelling of heat transfer and fluid flow in a silicon melt for the Czochralski process	Eivind J. Øvrelid
Malin Helander	F	Norwegian	Oxygen related thermal donors in monocrystakkine Si	2018	Thermal donors in Czochralski silicon wafers investigated by spectral imaging	Ingunn Burud
Matthew Engel Wermers	M	American	Agglomeration of solar silicon fines	2018	Recycling of Fine Silicon Particles for Solar Grade Silicon Production	Jafar Safarian
Amalie Berg	F	Norwegian	PL of multicrystalline silicon	2018	Temperature and injection dependent photoluminescence imaging of charge carrier lifetime in multicrystalline silicon wafers	Halvard Haug
Carolyn Willems	F	Canadian	Shading and snow effect on PV systems	2018	Effects of Shading on PV Power Production in Norwegian Climates	Eivind Øvrelid
Jørgen Sørhaug	M	Norwegian	TEM and AFM of Ag-implanted Si	2018	TEM characterization of tungsten implanted silicon - A study of a potential intermediate band solar cell material.	Randi Holmestad

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Kevin Lim	M	Australia	Kerf recovery	2018	Recovery and Utilisation of Kerf Waste from Silicon Wafering Process	Gabriela Tranell
Linn Tabita Milde	F	Norwegian	A study of the performance of two wall attached PV systems in a Nordic climate	2018	A study of the performance of two wall attached PV systems in a Nordic climate	Espen Olsen
Divya Narayanankutty	F	Indian	Nuclation mc-Si	2019	Nucleation and Growth of High Performance Multicrystalline Silicon (HPMC-Si) in Si3N4 and SiC Coated Crucibles	Marisa DiSabatino
Kjetil Karlsen	M	Norwegian	Oxide-based tandem	2019	Characterization of Li doped, magnetron sputtered Cu2O thin films	Eduard Monakhov
Helene Stalheim	F	Norwegian	Spectral PL in silicon wafers	2019	Hyperspectral photoluminescence of thermal donors in two Czochralski crystals pulled at different velocities	Ingunn Burud
Ingeborg Høiaas	F	Norwegian	Degradation effects in solar cells studied with spectral imaging	2019	Hyperspectral imaging as a tool to study solar induced photoluminescence from PV modules	Ingunn Burud
Markus J. B. Ristola	M	Norwegian	Preliminary studies of W-implanted Si	2019	Characterisation of tungsten-doped silicon - An intermediate band material candidate from ion implantation and nanosecond pulsed laser melting	Randi Holmestad
Siw Anita Hansen	F	Norwegian	Bifacial Solar Cells in Nordic Climate	2019	Bifacial Solar Cells in Nordic Climate	Eivind Øvrelid
Magnus Johansen	M	Norwegian	Materials for tandem solar cells	2019	ZnOxNy as a new material for top cell in tandem solar cells	Kristin Bergum
Hailu Asmare Libassie	M	Norwegian	PV systems analysis	2019	PV Installation System Analysis of Performance and Degradation Mechanisms	Terje Finstad
Aksel Pettersen	M	Norwegian	PV systems	2019	The Performance of Household PV Systems in Southeastern Norway	Espen Olsen
Tsz C. Daniel Cheung	M	Hong Kong or China	Quartz sand for Cz crucibles	2019	The Relationship between Hydroxyl Content and Viscosity of Fused Silica for the Czochralski Process	Kjell Wiik
Nathan Roosloot	M	Netherlands	Optimixation of coloured antireflection coatings for silicon solar cells	2019	Broadband angular colour stability of dielectric this film-coated pyramidial textured Si for photovoltaic	Albert Pullmann
Camilla Lie	F	Norwegian	Power prediction of PV systems	2019	Power Prediction of Photovoltaic System using Neural Network Models	Sathyajith Mathew
Osama Zariouh	M	Norwegian	Tandem cells	2020	Deposition of phase-pure Cu2O by magnetron sputtering	Edouard Monakov
Elin Dypvik Sørdahl	F	Norwegian	Materials for tandem solar cells	2020	HiPIMS deposition and characterization of amorphous ZnOxNy for solar cell applications	Kristin Bergum

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Ole-Kristian M Nese	M	Norwegian	PV systems	2020	Investigation of a PV System Using a Mathematical Model and Available Data	Anne-Gerd Imenes
Safia Hassan	F	Norwegian	Utilisation of Silicon-Kerf from Solar cell Wafering	2020	Distribution of Aluminum and Calcium between Silicon and CaO-Al2O3-SiO2 Slags at 1650 °C	Gabriella Tranell
Inger Fygle	F	Norwegian	Utilisation of Silicon-Kerf via Micro arc melting	2020	Production of Titanium alloys via aluminothermic reduction	Gabriella Tranell
Torleif Stensvold	M	Norwegian	Effect of sand treatment on the quartz crucible properties	2020	Effect of sand treatment on the properties of quartz crucible for the Czochralski process	Marisa DiSabatino
Gabriela Warden	F	Polish	Effect of pulling speed on oxygen related defects and electrical properties of CZ silicon ingots	2020	Study and investigation of oxygen related defects in Czochralski silicon ingots	Marisa DiSabatino
Ingvil Bergsbak	F	Norwegian	Simulations of tandem solar cells	2021	Numerical device simulations of ZnOxNy for Si-based tandem solar cells using Silvaco Atlas	Kristin Bergum
Ali Haider Raja	M	Norsk	PV Systems	2021	Performance assessment and degradation analysis of different grid-connected PV technologies installed in Trondheim, Norway	Marisa DiSabatino
Andreas Rosnes	M	Norwegian	Structural characterization of doped an undoped TiO2 thin films, using TEM-based techniques	2022	TEM Study of Cr, N Codoped TiO2 Thin Film	Randi Holmestad
Birk Ludwig S. Aigner	M	Norsk	PV/Battery system optimization	2021	System modeling and dispatch schedule optimization of combined PV battery system using linear optimization	Anne Gerd Imenes
Han Na Choi	F	Korean	Surface characterization of TiO2 thin films	2021	Surface Characterization of Titanium Dioxide Thin Film	Turid Reenaas
Herman Solstrand	M	Norwegian	Raman and SEM studies of doped and undoped TiO2 thin films	2021	Characterization of TiO2 based thin films using Raman spectroscopy	Turid Reenaas
Louise Viketun Skjøndal	F	Norwegian	Simulation and validation of the energy demand using photovoltaic systems to reduce roof snow load on building structures	2021	Simulation and analysis of the energy demands for roof-mounted photovoltaic snow mitigation systems	Thomas K. Thiis
Marcus G. Michaelsen	M	Norwegian	Optical and structural characterization of doped and undoped TiO2 thin films, using PL and XRD	2021	Pulsed Laser Deposited TiO2	Turid Reenaas
Mina Elise Ø. Holter	F	Norwegian	Effekt av albedo på tosidig effektgevinst for PV-moduler med toakset styring	2021	Tosidige solcellemoduler: påvirkningen albedo har på tosidig effektgevinst	Espen Olsen

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Mochamad Ilham Al Fariesy Irvansyah	M	Indonesia	Effect of cooling rate on the removal of impurities from MG-Si alloyed with MG	2021	Effect of the cooling rate on the removal of impurities from metallurgical-grade silicon alloyed with magnesium.	Marisa Di Sabatino
Mykhailo Khytko	M	Ukrainian	Performance and economical feasibility study of residential rooftop PV systems in Norway, Denmark and Ukraine	2021	Performance and economic feasibility study of residential rooftop PV systems in Norway, Denmark and Ukraine.	Marisa Di Sabatino
Ranvei Isaksen	F	Norwegian	PV module analysis	2021	IR- og dataanalyse for feildeteksjon og diagnostisering av solcellemoduler	Erik S. Marstein
Sigrid L. Larsen	F	Norwegian	PV systems analysis	2021	Investigation of Outdoor Performance of Silicon Photovoltaic Modules at Different Installation Angles	Anne Gerd Imenes
Siri B. Jensen	F	Norwegian	Studie av elektroluminescens og IV-kurver for å undersøke defektutvikling i solcellemoduler	2021	Studie av elektroluminescens og strømspenningskurver for å undersøke defektutvikling i solcellemoduler	Espen Olsen
Tore Skauge Bysting	M	Norwegian	Simulations of impurity type solar cells	2021	Simulation of the Impurity Photovoltaic Effect in GaAs Solar Cells	Turid Reenaas
Karl Edvin Herstad	M	Norwegian	Magnesiothermic reduction of SiO2and production of Silane gas	2022	Development of a Gas Analysis Method for Silane Gas	Gabriela Tranell
Ronald Reagon Ravi Kumar	M	Indian	Modeling and Analysis of vertical bifacial agrivoltaic test system at Skjetlein high school, Norway	2022	Modelling and Analysis of vertical bifacial agrivoltaic test system at Skjetlein high school, Norway	Marisa Di Sabatino
Rugile Balciunaite	F	Norwegian	A study of performance and degradation of floating PV in tropical climate	2022	A study of performance and degradation of floating PV in tropical climate	Espen Olsen
Sigrid Otterlei Sunde	F	Norwegian	Bifacial PV in Trondheim	2022	Energy Yield Analysis and Evaluation of Software Used for Different Configurations of Bifacial Photovoltaic Modules in Trondheim, Norway	Marisa Di Sabatino
Taeo Laue	M	American	Agri-PV modelling	2022	Using ray tracing to model agri-PV greenhouse energy production and PAR levels	Erik S. Marstein
Thale V. Stefansson	F	Norwegian	Forecasting	2022	Forecasting of Photovoltaic Power Production	Rune Strandberg
Thord Niri Gjesdahl Heggren	M	Norwegian	Fabrication and simulations of TiO2 based solar cells	2022	Improving Impurity Photovoltaic Solar Cells via Inhomogeneous Doping Concentrations in Proximity to the Depletion Region	Turid Reenaas

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Øyvind Bjørgum	M	Norwegian	PV modules analysis	2022	Power Loss Estimation of PV Modules Through IV-characteristics and Image Analysis	Anne Gerd Imenes
Stine Evjeberg Hansen	F	Norwegian	Solar cell simulations	2022	Simulation of the Impurity Photovoltaic Effect in TiO2 Solar Cells Using SCAPS	Turid Reenaas
Andreas Løkkeberg	M	Norwegian	Soiling data in PV plants	2022	Analysis of soiling data and its effects on the performance of utility-scale PV plants	Espen Olsen
Arthika Sivananthan	F	Norwegian	Bubble Distribution in Heat Treated Fused Quartz Crucible for Monocrystalline Silicon Ingots	2022	Bubble distribution in heat treated fused quartz crucibles for monocrystalline silicon ingots	Marisa Di Sabatino
David A. Nilssen	M	Norwegian	Thermal donors in p-type Cz-Si	2022	Deteksjon av termiske donorer i p-type Cz-Si ved romtemperatur	Espen Olsen
Dina Martinsen	F	Norwegian	PV systems modeling	2022	Performance Modeling of Bifacial PV Power Plants in a Nordic Climate	Marisa Di Sabatino
Erlend North	M	Norwegian	Upconversion	2022	Quinizarin as Organic Sensitizer in LnF3 Thin Films for Photon Upconversion	Ola Nilsen
Hannah Massey	F	Norwegian	Hydrogen production from PVs	2022	Hydrogen production modelling of a water electrolyser with PV data as input	Erik. S. Marstein
Herman S. Ljosland	M	Norwegian	PV module fault detection	2022	Comparison of Fault-Detection Methods in Photovoltaic Modules	Anne Gerd Imenes
Jacob Krum Thorning	M	Norwegian	Modelling of vertical bifacial PV in Nordic countries	2022	Validation and comparison of irradiation models for bifacial solar systems in the Nordics	Marisa Di Sabatino
Jacob Wilder Ng	M	American	Characterization of Cr and N co-doped TiO2	2023	Glow Discharge Optical Emission Spectroscopy for Elemental Characterization of Doped TiO2 Thin Films made by Pulsed Laser Deposition	Turid Reenaas
Joseba Miren Ormaetxea Orobengoa	M	Spanish	Photoluminescence spectroscopy of TiO2	2023	Coloured intermediate band solar cells	Turid Reenaas
Rasmus Hoholm	M	Norwegian	Simulations of optoelectronic properties of TiO2	2023	Electronic and Optical Properties of TiO2, and the Potential of Doped TiO2 for the Use in Intermediate Band Solar Cells	Jon-Andreas Støvneng
Sarah Nyeki	F	French	Characterization of optoelectronic properties of doped and undoped TiO2	2023	Optical Characterization of Intermediate Band Material	Turid Reenaas
Adrian Bjørge Ulven	M	Norwegian	PV modules analysis	2023	Analysis of Spectral Irradiance Variations and Their Impact on the Performance of Different Photovoltaic Modules	Anne Gerd Imenes
Amalie Robsahm	M	Norwegian	PV system simulation	2023	Simulation of a vertical bifacial PV system compared to measured values	Espen Olsen

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Harry Mahli	M	USA	Analysis of an Agrivoltaic System at Skjetlein High School, Norway	2023	Analysis of an Agrivoltaic System at Skjetlein High School, Norway	Marisa Di Sabatino
Madelen Flesland	F	Norwegian	Agri-PV modelling	2023	AgriPV i Ås – en modellbasert simulering av energiproduksjon og planteveks	Espen Olsen
Martin Krebs-Kristiansen	M	Norwegian	PV system analysis	2023	Performance Analysis of PV Power Plants Across Norway	Anne Gerd Imenes
Mirabai Hillestad	F	Norwegian	PV modules analysis	2023	Diagnosis of Bifacial PV Modules Using Photoluminescence Imaging from the Rear in Direct and Diffuse Irradiance	Ingunn Burud
Andreas Ranje	M	Norwegian	Agri-PV systems	2023	Autonom landbruksrobot i en solcelledrevet jordbærpolytunnel med batterilagring	Espen Olsen
Mari Valle Kjelby	F	Norwegian	A study of correlation between photo-luminescence and IV-curves in solar modules	2023	Studie av korrelasjon mellom fotoluminescens og IV-kurver i solcellemodule	Espen Olsen
Mathea Salmi Marjavara	F	Norwegian	Visualization and quantification of PID in solar modules using PL imaging in daylight	2023	Visualisering og kvantifisering av PID i solcellemoduler ved hjelp av PL-avbildning i dagslys	Espen Olsen
Vilma Helena Erika Kristiansson	F	Norwegian	Lifetime measurements in silicon	2023	Temperature-dependent carrier lifetime measurements on silicon wafers and bricks	Marisa Di Sabatino
Amanda Lindholm	F	Norwegian	Effect of silicon feedstock on structure loss compared to measured values	2024	Analyzing the impact of feedstock on the structure loss occurrence in Czochralski silicon growth	Marisa Di Sabatino
Vilde Frydenlund Norling	F	Norwegian	Silicon recycling from EOL PV	2024	Characterization of Recovered Silicon from End-of-Life PV Modules, and its Refining by Leaching and Vacuum Refining Techniques	Jafar Sabarian
Stein Arne Haaland	M	Norwegian	PV module simulations	2024	Optimalisering av strålesporingssimuleringer for tosidige solceller i Rhino 3D	Arnkell J. Petersen
Mette Lie	F	Norwegian	Floating PV	2024	Energy Yield Assessment of Floating Solar PV on Inland Water Bodies in Norway	Arnkell J. Petersen
Erlend Kringlebotten	M	Norwegian	PV module modelling and analysis	2024	Comparing Measured to Modelled Spectral Irradiance for EY Assessments of Tandem PV Modules	Gaute Otnes

Name	M/F	Nationality	Scientific area	Year in the centre	Thesis title	Main thesis Advisor
Simone Milani	F	Italian	Agri-PV systems	2024	AgriPV as a Means to Increase Drought Resilience Water Benefits in Olive Orchards: the Impact of AgriPV Systems in Southern Italy	Erik Marstein
Håkon Holthe	M	Norwegian	Phase Segregation Mapping in Perovskite Solar Cells Using Hyperspectral Photoluminescence Imaging	2024	Phase Segregation Mapping in Perovskite Solar Cells Using Hyperspectral Photoluminescence Imaging	Espen Olsen
Jon Erik Nesse	M	Norwegian	Reducing Grid Connection Requirements	2024	Case Study of Alternatives to Grid Expansion	Anne Gerd Imenes
Kristian Brohaug	M	Norwegian	Reducing Grid Connection Requirements	2024	Case Study of Alternatives to Grid Expansion	Anne Gerd Imenes
Khamzat Saitov	M	Norwegian	Floating PV	2024	Numerical modelling, calibration and analysis of an offshore floating photovoltaic concept	Zhiyu Jiang
Eskil B. Furset	M	Norwegian	PV systems	2024	Håndtering og Integrering av Solenergiens Overskuddsproduksjon i Distribusjonsnettet	Rune Strandberg
Mathias H. Hagane	M	Norwegian	PV systems	2024	Håndtering og Integrering av Solenergiens Overskuddsproduksjon i Distribusjonsnettet	Rune Strandberg
Nicolle Tello Diaz	F	Columbian	Tandem solar cell	2025	Copper based oxides for tandem solar cells	Eduard Monakhov
Solveig Pettersen	F	Norwegian	Studier av vertikalmonterte dobbeltsidige moduler med utendørs fotoluminescens	2025	Analyse av lysindusert degradering i dobbeltvirkende PV-moduler ved bruk av fotoluminescens-avbildning	Ingunn Burud
Even Traagstad Gundersen	M	Norwegian	High purity quartz crucibles	2025	Investigating how bubbles influence the viscosity of high purity quartz crucibles	Marisa Di Sabatino
Tord Tinius Løgavlen.	M	Norwegian	Forecasting for newly installed PV-systems	2025	Day-Ahead PV Power Forecasting for New Installations: Comparing Physical, Machine Learning, and Transfer Learning Models	Rune Strandberg

Dissemination 2017-2025 from FME SUSOLTECH

The activities have resulted in the following public information about research (articles, books, exhibition):

1. Solceller blir mest sannsynlig fremtidens viktigste energikilde, men kommer de fort nok til å redde oss? Halvard Haug, Tidsskriftet Naturfag, utgave 1 2019
2. Smarte hus om solcellekraftverk, kapittel i Det nye digitale Norge, Erik. S. Marstein, John Grieg Forlag 2019
3. Slik kan en bedre bakeform gi mer effektiv solcelleproduksjon, Gabriela Kazimiera Warden, NTNU Teknad, blogg 2022
4. Omelett med slegge og q-tips, Einsteins fartsgrense, og Andreas ville veid mer om han ble født i Oslo, Per-Anders Hansen, Jøss! Podcast #51, 11.12.2021

The activities have resulted in the following presentation in mass media:

1. Ser fortsatt etter tomt, Smaalenenes avis, Lise-Kari Holøs, 28. august 2018
2. Ser fortsatt etter tomt, Smaalenene.no, Lise-Kari Holøs, 28. august 2018
3. Dynatec i Askim er annerledesbedriften, Mulighetsriket Østfold (film på nett og fb),8. juni 2018
4. Planlegger ny fabrikk til 50 mill, Smaalenenes avis, Lise-Kari Holøs, 23. mai.2018
5. Planlegger ny fabrikk til 50 mill, Smaalenene.no, Lise-Kari Holøs, 23. mai.2018
6. Søker en større tomt, Smaalenenes avis, Guri Rønning, 25. april 2018
7. Søker en større tomt, Smaalenene.no, Guri Rønning, 25. april 2018
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19. Numerical device simulation of temperature coefficients in compensated silicon solar cells, Halvard Haug, NSCC 2018 May 2nd. Oral Presentation, SON
20. Strain dependent defect ionization energies in Cuprous Oxide; Heine Riise; NSCC 2018 May 3rd. Oral Presentation, SON
21. Extraction of barrier heights of Pd and Pt Schottky diodes on hydrogenated TiO2, Julie Bonkerud, NSCC 2018 May 3rd. Oral Presentation, SON
22. Nitrogen Doping of Sputtered Cuprous Oxide Thin Films by Ion Implantation, Martin Nyborg, NSCC 2018 May 3rd. Oral Presentation, SON
23. Architectural integration, challenges and possibilities, Barbara Szybinska Matusiak, NSCC 2018 May 3rd. Oral Presentation, SON
24. Research-based design of PV plants on commercial buildings in Norway, Trygve Mongstad, NSCC 2018 May 3rd. Oral Presentation, SON
25. Environmental challenges related to PV unit's production, operation and decommissioning, Juliette Leyris, NSCC 2018 May 3rd. Oral Presentation, SON
26. Monitoring of PV System Performance and Degradation, Anne Gerd Imenes, NSCC 2018 May 3rd. Oral
27. Combined refining of silicon at the Norwegian laboratory for silicon-based solar cell technology. Jafar Safarin, Eivind Øvrelid, NSCC 2018, May 2nd Poster Presentation, Son
28. Annealing Kinetics of the carbon–dioxygen complex in proton irradiated p-type Si H. M. Ayedh, A. A. Grigorev, A. Galeckas, B. G. Svensson and E. Monakhov, NSCC 2018, May 2nd Poster, Son
29. A hyperspectral photoluminescence imaging study of oxygen related defects in CZ-silicon material in the temperature range of thermal donors, Malin Helander, Espen Olsen, Torbjørn Mehl, Rune Søndenå and Ingunn Burud, NSCC 2018, May 2nd Poster Presentation, Son
30. Study of higher-order oxygen-related defects in Si using FT-IR spectroscopy, Philip M. Weiser, Edouard V. Monakhov, and Bengt G. Svensson, NSCC 2018, May 2nd Poster Presentation, Son
31. Exploring the activation barriers of dislocation generation from grain boundaries in silicon with atomistic modelling. Simen Nut Hansen Eliassen, NSCC 2018, May 2nd Poster Presentation, Son
32. Thermal stability and electronic properties of defects in high-dose proton irradiated, A. A. Grigorev, H. M. Ayedh, A. Galeckas, B. G. Svensson, and E. V. Monakhov, NSCC 2018, May 2nd Poster Presentation, Son
33. Temperature sensing using luminescent thin-films, Michael Getz, Ola Nilsen, Per-Anders Hansen, NSCC 2018, May 2nd Poster Presentation, Son
34. Hyperdoped silicon for intermediate band solar cells, Hogne Lysne, Heidi Sæverud Hauge, Mohammadreza Nematollahi, Marisa Di Sabatino, Randi Holmestad and Turid Reenaas, NSCC 2018, May 2nd Poster Presentation, Son
35. Theoretical studies of optoelectronic properties of kesterite type Cu2ZnSnS4 (CZTS) and thin film solar cells, D. Mamedov, M. Klopov, and S. Zh. Karazhanov, NSCC 2018, May 2nd Poster Presentation, Son
36. Exploring networks for knowledge development and diffusion in technological innovation systems, Maria Tsouri & Jens Hanson, NSCC 2018, May 2nd Poster Presentation, Son
37. Epitaxial growth of silicon by electron beam evaporation deposition, M. Stange, R. Dahl-Hansen, T.O. Sunde, A. S. Azar, A. Ulyashin, NSCC 2018, May 2nd Poster Presentation, Son
38. Dynamic observation of dislocation generation and interaction with grain boundaries during directional solidification of silicon, M.G. Tsoutsouva, G. Stokkan, B. Ryningen2, T. Riberi – Béridot, G. Regula, G. Reinhart, N. Mangelinck-Noël, NSCC 2018, May 2nd Poster Presentation, Son
39. Effects of Shading on PV Power Production in Norwegian Climates, Carolyn Willems, NSCC 2018, May 2nd Poster Presentation, Son
40. Numerical Analysis of Thermal Donors Effect on the Quality of Czockralski Growth Silicon Crystal, Moez Jomâa, Mohammed MHamdi, John Atle Bones, Mari Juel, SINTEF Industry, NSCC 2018, May 2nd Poster Presentation, Son

41. Status and trends in silicon wafer-based photovoltaics, and current activity at IFE, Halvard Haug, FORENT Gemini seminar on photoelectrochemistry and photovoltaics
42. Hyperdoped silicon for intermediate band solar cells, Hogne Lysne , Heidi Sæverud Hauge, Mohammadreza Nematollahi , Marisa Di Sabatino, Randi Holmestad and Turid Reenaas, Quantsol summer school, 2018
43. The renewable energy revolution - Foredrag på Teknas CO2-konferanse, Erik Stensrud Marstein, 2018
44. Solceller? - Invitert foredrag (pot vit) på PechaKucha vol 45 (Oslo), Erik Stensrud Marstein,15/2 2018
45. Welcome and introduction - Åpningsforedraget på NSCC 2018 (Son) Erik Stensrud Marstein, 2/5 2018
46. Silicon solar cells - Foredrag på Norsk Materialteknisk Konferanse (Oslo) Erik Stensrud Marstein, 31/5 2018
47. BIPV i Norge - Invitert foredrag på Solenergidagen (Oslo) Erik Stensrud Marstein, 6/9 2018
48. Solar cell technology - Foredrag på LUCS sommerskole (Simulasenteret) Erik Stensrud Marstein, 6/9 2018
49. BIPV i Norge – muligheter og utfordringer - Innledende foredrag på BIPV-dagen (Oslo) Erik Stensrud Marstein, 7/9 2018
50. Grønne tak med solenergiproduksjon, Clean Tuesday, Solenergiklyngen Oslo 12. juni 2018, Romeo Apetrei-Thomassen
51. Presentasjon av OBY utslippsfrie byggeplass, OBY hovedkontor, OSLO 15. oktober 2018, Romeo Apetrei-Thomassen
52. Presentasjon til deltakelsen til OBY i FoU- og EU-prosjekter, samt satsningen på solcelleanlegg / BIPV / EpoG, Årsmøte Solar Energy, Solenergiklyngen, ASKER 12.november 2018, Romeo Apetrei-Thomassen
53. Presentasjon av FoU- og EU-prosjektet, Oslo Kommune 6. september 2018, Romeo Apetrei-Thomassen
54. BIPV i Omsorgsbygg, BIPV dagen 7. september 2018, Oslo, Espen Mikkelsen
55. Research on solar silicon feedstock in the Norwegian solar community, Jafar Safarian, Int. seminar on material loss and recycling in the whole value chain for PV silicon production and use, 2019
56. Kinetics of P removal from Si-Al melts, Arma Hoseinpur, NSCC 2019
57. Elements behavior in solidification of Mg-doped silicon and their removal in acid leaching, Mengyi Zhu, NSCC 2019
58. Structure Loss in Czochralski Silicon Growth: Statistical Analysis of Growth Parameters and Modeling of Thermal Fluctuations, Øyvind S. Sortland, NSCC 2019
59. Statistical analysis of growth parameters and structure loss in Czochralski silicon production, Øyvind S. Sortland, Eivind J. Øvrelid, Mohammed M'Hamdi, Hendrik Schön, and Marisa Di Sabatino, Norsun 17/1-19
60. Gas refining for boron removal from silicon, Øyvind S. Sortland, Foredrag i kurset Theory and Processes for Solar Grade Silicon Production, 16-17/10-19
61. Monocrystalline silicon material quality loss and recycling in Czochralski process, Øyvind S. Sortland, Presentasjon i seminaret Material loss and recycling in the whole value chain for PV silicon production and use, 18/10-19
62. Simulation of Impurities diffusion and precipitation during wafer heat treatment, Mohammed M'Hamdi, S. Gouttebroze, NSCC 2019
63. Production and characterization of fused silica for Czochralski process, T.C. Daniel Cheung, Astrid Marie Muggerudm Kjell Wiik, Paul Inge Dahl, John Atle Bones, NSCC 2019
64. Light sensitive defects in p-type high performance multicrystalline silicon wafers, Rune Søndenå, NSCC 2019
65. How can we do defect defective work by investigating the trouble they make? - PL-based lifetime spectroscopy with high spatial resolution, Halvard Haug, NSCC 2019
66. High Rate Deposition of Epitaxial Silicon by E-beam, Marit Stange, NSCC 2019
67. Detecting oxygen related defects such as thermal donors in Czochralski silicon cross-sections using, Helene Stalheim, Ingunn Burud, Espen Olsen, Torbjørn Mehl, NSCC 2019

68. Identifying recombination centers in Silicon by lifetime spectroscopy, Marie Syre Wiig, and Rune Søndenå, Erik S. Marstein and Halvard Haug, NSCC 2019
69. Silicon-based tandem solar cells, Kristin Bergum, NSCC 2019
70. Lithium Doped reactive Magnetron Sputtered Cu2O Thin Films, Martin Nyborg, NSCC 2019
71. Efficiency of coloured and transparent PV, Tore Koslås, Integrated Solar Solutions Conference, 2019
72. Tungsten doped silicon for intermediate band solar cells, Hogne Lysne, Markus Ristola, Jørgen Sørhaug, Marisa Di Sabatino, Randi Holmestad and Turid Reenaas, NSCC 2019
73. A comparative analysis of wall-mounted mc-Si and CIGS modules, Gaute Otnes, NSCC 2019
74. The innovation system for solar photovoltaics in Norway: the role of knowledge development and policy, Dimitra Chasanidou & Jens Hanson, NSCC 2019
75. The creation of a website for Norwegian PV plants, Lisa Kvalbein, NSCC 2019
76. Accelerated ageing of PV-module interconnects, Gaute Otnes, NSCC 2019
77. Outdoor monitoring of spectral irradiance for PV module performance testing, Basant Raj Paudyal, Anne Gerd Imenes, NSCC 2019
78. Muligheter og utfordringer knyttet til Bygningsintegrerte solceller (BiPV) i Norge i 2018 Report, Lisa Kvalbein, Erik Stensrud Marstein, Tore Kolås, Bjørn Petter Jelle, Josefine Selj, Sean Erik Foss, Trine Kopstad Berentsen, Barbro Nordby, Inger Strand, Ragnhild Bjelland-Hanley,
79. Monitoring of temperature related behaviour of a BIPV solar roof in Trøndelag, Gaute Stokkan, Eivind Øvrelid, Bendik Sægrov-Sorte. NSCC 2019
80. High purity quartz for high quality solar crucibles, Astrid Marie Muggerud, NSCC 2019
81. Effect of silicon alloying on P removal kinetics in vacuum refining, Arman Hoseinpur, NSCC 2019
82. Hyperspectral Photoluminescence imaging as a tool to study degradation of outdoor Silicon solar panels, Marija Vukovik, NSCC 2019
83. Goal of the crucible activity in FME Susoltech, Mari Juel, Solar Industry Forum VI Crucibles for Cz-Si Production, 29. Aug, 2019
84. Overview of Mater Thesis on Crucibles at NTNU, Marisa Di Sabationo, Mari Juel, Solar Industry Forum VI Crucibles for Cz-Si Production, 29. Aug, 2019
85. Effect of humidity and viscosity on fused silica, Tsz Chung Daniel Cheung, Solar Industry Forum VI Crucibles for Cz-Si Production, 29. Aug, 2019
86. A model for bubble growth in Cz crucible, Mohammed M'Hamdi, Solar Industry Forum VI Crucibles for Cz-Si Production, 29. Aug, 2019
87. Degradation behaviour of a Norwegian PV plant, Hailu Asmare Libassie, NSCC 2019
88. Multi-crystalline Silicon Module Degradation Analysis Using Operational Data Under Norwegian Climatic Conditions, Hailu Asmare Libassie, NSCC 2019
89. Silicon doped with ultra-high doping concentrations of tungsten for intermediate band solar cells, Hogne Lysne, Markus Ristola, Jørgen Sørhaug, Marisa Di Sabatino, Randi Holmestad og Turid Reenaas, NSCC 2019
90. TEM characterization of tungsten implanted silicon for intermediate band solar cells, Jørgen Sørhaug, Hogne Lysne, Markus J. B.Ristola,Marisa Di Sabatino,Turid Reenaas and Randi Holmestad, NSCC 2019
91. The effect of system design on PV performance, Aksel Pettersen, Mari B. Øgaard, Helene B.Tømmerbakke, Josefine H. Selj and Espen Olsen, NSCC 2019
92. PV: From concept to large scale industry – Technology trends and opportunities for Norwegian companies, Erik S. Marstein, Invitert foredrag Smart Energy Network 28/11, Oslo 2019
93. Creation of Product Category Rules (PCR) for Solar Modules: https://www.epd-norge.no/pcr-register/npcr-029-2020-part-b-for-photovoltaic-modules-article2642-353.html
94. Facade integrated PVs/FIPV, Changying Xiang, Report, NTNU Energi og miljø Gruppe

95. PV fargepalett for Trondheim, Changying Xiang, Barbara Szybinska Matusiak, Oral presentation, NTNU lys og farge senter
96. Welcome and status, Erik S. Marstein, NSCC 2021
97. Making the solar business circular, Ronny Glockner, NSCC 2021
98. Impurity analysis in Al-Si alloys by SIMS: the role of the primary beam, Alexander Azarov, NSCC 2021
99. Gallium- and Boron-doped hpmc-Si Wafers Studied by Hyperspectral Photoluminescence Imaging, Torbjørn Mehl, NSCC 20201
100. A study on the wettability and chemical stability of Si3N4:Si2ON2 coating for application to photovoltaic silicon crystallization, Rania Hendawi, NSCC 2021
101. In situ spectroscopic investigation of water and hydroxyl groups during heat treatment of high purity natural quartz, Bartłomiej A. Gaweł, NSCC 2021
102. Illuminated Annealing of multicrystalline and monocrystalline silicon wafers containing B, P, and Ga, Rune Søndenå, NSCC 2021
103. Improving ALD-Al2O3 surface passivation of Si solar cells by using native SiOx, Michael N. Getz, NSCC 2021
104. NCR - World class scale in northern Norway, Øyvind Østrem, NSCC 2021
105. Mechanism of the Magnesiothermic Reduction of Quartz at Different Reaction Conditions, Azam Rasouli, NSCC 2021 2.-3. November 2021
106. Electronic properties and the dominant levels in ZnON, Kjetil Karlsen, NSCC 2021
107. Colour and Gloss of PV-modules for Building Integration, Tore Kolås, NSCC 2021
108. Status of the solar industry in Norway, Maja Busch Sevaldsen, NSCC 2021
109. Different Reaction Conditions, Azarov, Alexander; Hoseinpur, Arman; Safarian, Jafar; Monakhov, Eduard, NSCC 2021 2.-3. November 2021
110. Yield enhancement of roof-installed bifacial PV system, Junjie Zhu, NSCC 2021
111. Dominating migration barrier for intrinsic defects in gallium oxide at and above room temperature, Azarov, Alexander; Venkatachalapathy, Vishnukanthan; Monakhov, Eduard; Kuznetsov, Andrej, 31st International Conference on Defects in Semiconductors (ICDS-31)
112. Dose-rate effect in β-Ga2O3, Azarov, Alexander; Venkatachalapathy, Vishnukanthan; Monakhov, Eduard; Kuznetsov, Andrej, The XXV International Conference on Ion-Surface Interactions (ISI-2021)
113. Radiation defect dynamics in β-Ga2O3: ion flux vs irradiation temperature, Azarov, Alexander; Venkatachalapathy, Vishnukanthan; Monakhov, Eduard; Kuznetsov, Andrej, Applied Nuclear Physics conference (ANPC-2021)
114. Gas refining of silicon for B removal (oral presentation), Arman Hoseinpur Kermani, the European PV Solar Energy Conference (EU PVSEC) 2021
115. Solceller lever lenger i Norge enn i varmere strøk, Josefine Selj, Eivind Bekken Sveen, Gaute Otnes, Dagens Næringsliv, 18.12.2020
116. Sol på en fredag – bifacial spesial, Heine Nygard Riise m.fl. 19.11.2021, Solenergiklyngen
117. CleanTuesday – BIPV frokostwebinar - 9. mars 2021, Erik Stensrud Marstein m.fl., Solenergiklyngen
118. Bærekraftig produksjon av solcellematerialer - 3. juni 2021, Frokostwebinar, Erik Stensrud Marstein m.fl., Solenergiklyngen
119. The Norwegian Solar Energy Innovation System, Chasanidou, D., Hanson, J. & Normann, H.E. NTRANS report series, 21.06.2021
120. Outdoor Photoluminescence and Electroluminescence Imaging of Silicon Modules in a String, Ingunn Burud, NSCC 2021
121. Low Carbon Footprint as a business advantage, Trude Nysæther, NSCC2021
122. Bifacial gain in Nordic conditions, Magnus Moe Nygård, NSCC 2021

123. Temperature profiles of field-aged photovoltaic modules affected by optical degradation, Oscar Kwame Segbefia, NSCC 2021
124. Inspection and condition monitoring of large-scale photocoltaic power plants: A review of imaging technologies, Ingeborg Høiaas, NSCC 2021
125. Adapting the design of ground mounted solar power plants to snowdrift climates, Iver Frimannslund, NSCC 2021
126. PV snow losses in Norway: how much power is lost, and can it be predicted? Mari Øgaard, NSCC 2021
127. Testing Bifacial solar panels in agrivoltaics – a Do-it-yourself project, Gaute Stokkan, NSCC 2021
128. High Purity Quartz - Performance Raw Materials for the Solar Industry, Benny Hallam, SINTEF/ NTNU Webinar series, December 2020, on-line.
129. Bygningsmessig integrasjon: kontrast eller harmoni?, Barbara Matusiak, Arbeidspakkemøte WP3/WP4 vår 2021
130. Thin film interference coatings for coloured and efficient PV, Tore Kolås, Arbeidspakkemøte WP3/WP4 vår 2021
131. Toward Architectural Design Method for Coloured FaÇade Integrated Photovoltaics, Changying Xiang, Arbeidspakkemøte WP3 høst 2021
132. Simulating a tandem solar cell using SILVACO, Ingvild Bergsbak, Arbeidspakkemøte WP3 høst 2021
133. Broadband angular colour stability of dielectric thin film-coated pyramidal textured Si for photovoltaics, Nathan Roosloot, Arbeidspakkemøte WP3/WP4 vår 2021
134. PLD grown Cr and N co-doped TiO2 as a potential intermediate band solar cell, Hogne Lysne, Arbeidspakkemøte WP3/WP4 vår 2021
135. Pixelation method for façade integrated photovoltaics, Changying Xiang, Arbeidspakkemøte WP3/WP4 vår 2021
136. Lanthanide-based thin films for light conversion, Vegard Rønning, Arbeidspakkemøte WP3/WP4 vår 2021
137. Design and fabrication of colored solar cells for BIPV applications, Ørnulf Nordseth, Arbeidspakkemøte WP3/WP4 vår 2021
138. Performance of BIPV and BAPV systems in Norway: Experiences and results from the BIPVNO project", Anne Gerd Imenes, SUSOLTECH combined WP3 & WP4 meeting (Teams online), 03.05.2021.
139. PV Systems Research at University of Agder, Anne Gerd Imenes, SUSOLTECH WP4 seminar (Teams online), 16.06.2021.
140. Imaging for PV module monitoring, O. S. Kwame, SUSOLTECH WP4 online workshop at NMBU, 23 Sept 2021.
141. Complex oxides for intermediate band solar cells, Ingrid Hallsteinsen, Årsmøte FME Susoltech 31.08.2021
142. Tandem solar cells, Martin Nyborg, Årsmøte FME Susoltech 31.08.2021
143. Colors and esthectics in BiPV, Barbara Matusiak, Tore Kolås, Ørnulf Nordseth, Årsmøte FME Susoltech 31.08.2021
144. Magnesiothermic reduction of quartz, Azam Rasouli, Årsmøte FME Susoltech 31.08.2021
145. SIMS analysis of Si samples, Alexander Azarov, Årsmøte FME Susoltech 31.08.2021
146. Investigation of the refining limitation of silicon feedstock by metallurgical treatments, Kai Tang, Årsmøte FME Susoltech 31.08.2021
147. Trends in solar cell technologies and its impact on crucible properties, Benny Hallam, Årsmøte FME Susoltech 31.08.2021
148. How to measure the properties of next generation quartz crucibles?, Gabriela Warden, Årsmøte FME Susoltech 31.08.2021
149. Advance characterization of degradation mechanisms in solar cell silicon, Philip Weiser, Årsmøte FME Susoltech 2021,

150. Study on alignment of policy needs, Jens Hansson, Årsmøte FME Susoltech 31.08.2021
151. Performance of the bifacial plant at Isola AS, Heine Nygard Riise, Årsmøte FME Susoltech 31.08.2021
152. TBD, Gaute Stokkan, Årsmøte FME Susoltech 31.08.2021
153. Pulsed laser deposition of doped TiO2 thin films with lateral composition gradients, Hogne Lysne, NSCC 2021
154. Colour and Gloss of PV-modules for Building Integration, Tore Kolås, Arne Røyset, Ørnulf Nordseth, Chang Chuan You, Barbara Matusiak, Changying Xiang, NSCC 2021
155. Fabrication and characterization of dielectric thin film stacks for colored BiPV applications, Chang Chuan You, NSCC 2021
156. Architecturally attractive BIPV facades with efficient coloured PV, Tore Kolås, Building integrated PV webinar
157. Solar hydrogen - Adapting sunlight to fit the technology, Per-Anders Hansen, Foredrag, Impact Breakfast (UiO:Energy)
158. Evolution of microstructure and stess in homoepitexial Si films grown by electron beam evaporation, R. Dahl-Hansen, M. Stange, NSCC 2021
159. Viscosity measurements on fuesed quartz: challenges and methods development, G.K. Warden, M.Juel, B.A. Gawel, M.M'hamdi, M. Di Sabatino, NSCC 2021
160. In-situ obervations of dislocations during directional solidifaction, G. Stokkan, M.G.Tsoutsouva, B. Ryningen, NSCC 2021
161. Fast degradation and recovery of Ga doped wafers, Per-Anders Hansen, NSCC 2021
162. Characterization of hydrogen-related impurities in silicon and their connection to light-induced degradation, P.M. Weiser, R. Søndenå, R. Carcamo, A.G. Farzad, and E. Monakhov, NSCC 2021
163. How to optimize the utilization of PV in a hybrid off-grid energy system, M. Juel, G. Stokkan, T. Xu, Y. Raka, S.M. Hanetho, NSCC 2021
164. Dynamic observation of dislocation evolution and interaction with twin boundaries in silicon crystal growth using in-situ synchrotron X-ray diffraction imaging, M. G. Tsoutsouva, G. Stokkan, B. Ryningne, NSCC 2021
165. Low temperature heat treatment of multicrystalline silicon wafer, G. Stokkan, B. Ryningen, Y. Xu, I Bragestad, NSCC 2021
166. Modelling of bifacial PV-modules using Ray Tracing, M.E. Holter, E. Øvrelid, E.Olsen, NSCC 2021
167. Testing Testing Bifacial solar panels in agrivoltaic- a Do-it-yourself projectBifacial solar panels in agrivoltaic- a Do-it-yourself project, G. Stokkan, NSCC 2021
168. Steady-state Photocapacitance Spectroscopy of Intrinsic Defects in Electron-Irradiated β-Ga□O□, A. Langørgen, R.M. Karsthof, P.M. Weiser, O. Cavani, R. Grasset, Y. K. Frodason, I.J.T. Jensen, L. Vines, 31st International Conference on Defects in Semiconductors (ICDS), July 26th-30th, 20221, Oslo
169. Diffusion of donor dopants in β-Ga2O3 and interplay with gallium vacancies, P.P. Krzyzaniak, Y.K. Frodason, P.M. Weiser, L. Vines, K.M.H Johansen, 31st International Conference on Defects in Semiconductors (ICDS), July 26th-30th, 20221, Oslo
170. Effect of pulling speed on oxygen related defects in Czochralski silicon ingots, G.K. Warden, M. Juel, J.A. Bones, M. Di Sabatino, 31st International Conference on Defects in Semiconductors (ICDS), July 26th-30th, 20221, Oslo
171. Evolution of hydrogen-related defects in float zone-grown silicon wafers under dark annealing: resistivity change vs. FT-IR, Philip Michael Weiser, Rune Søndenå, and Eduard V. Monakhov, 31st International Conference on Defects in Semiconductors (ICDS), July 26th-30th, 20221, Oslo
172. Identifying defect parameters for common recombination centers in multicrystalline silicon by temperature and injection dependent lifetime spectroscopy, Marie Syre Wiig, and Rune Søndenå, Erik S. Marstein and Halvard Haug, 11th International Conference on Crystalline Silicon Photovoltaics, April 19th - 23rd, 2021, Emmerthal
173. Czochralski growth of single crystals for high efficiency solar cell applications. Eivind Øvrelid, Martin Bellmann, Balram Panjwani, Pål Tetli, NSCC 2021

174. Presentation of ICARUS: Innovative EcoEfficient processing and refining routes for secondary raw materials from silicon ingots and wafer Bellmann, Ryningen, NSCC 2021

175. Diamond sawing for crystalline silicon wafering Pål Tetlie, Sergio Armada, Arne Røyset, Julian Kökler, Gabriella Tranell, Birgit Ryningen, NSCC 2021

176. Measuring moisture ingress through FPV module edge sealants by a gravimetric method Nathan Roosloot, Mike Dallaway, Bjørn Riise and Gaute Otnes, NSCC 2021

177. Developing photon conversion structures for PV applications Vegard Rønning, NSCC 2021

178. Extended Thermal Cycling of Shingled Cell Interconnects Nathan Roosloot, Junjie Zhu, Sean Erik Foss and Gaute Otnes, NSCC 2021

179. Evaluation of irradiance models for bifacial PV systems Dina Martinsen, Magnus Moe Nygård, Marie Syre Wiig, Heine Nygard Riise, Mari Øgaard, Gaute Otnes, Marisa di Sabatino og Erik Stensrud Marstein, NSCC 2021

180. Balcony design with integrated PVs Changying Xiang, NSCC 2021

181. Veikart for den norske solbransjen mot 2030, Erik. S. Marstein, Geminisentermøte 29/4

182. Solar cell technology, Erik. S. Marstein, Fysikermøte 21/6-2021

183. Solar cell technology, Erik. S. Marstein, Sundvolden 26/8-21

184. Energi21, Erik. S. Marstein, solkraftmøte 7/9-21

185. Solbransjen anno 2021, Erik. S. Marstein, Solenergiklyngen 23/9-21

186. Fremtidig behov for teknologiutdanning innen fornybare energisystemer, Erik. S. Marstein, Foredrag Innspillseminar, Lillestrøm 22/10-2021

187. Identification of Fe-, Ti- and H-related Charge-state Transition Levels in β-Ga2O3, C. Zimmermann, Y.K. Frodason, J.B. Varley, E.F. Verhoeven. V. Rønning, P.M. Weiser, A. W. Barnard, G. Zbigniew, K. Irmscher, W. E, Meyer, F.D. Auret, A. Karjalainen, A. Langøren, R.M. Karsthof, L. Vines, 31st International Conference on Defects in Semiconductors (ICDS), July 26th-30th, 20221, Oslo

188. Multistability of Ga-O divacancies in β-Ga2O3, Y.K. Frodason, C.Zimmermann, E.F. Verhoeven. P.M. Weiser, L. Vines, J.B. Varley, 31st International Conference on Defects in Semiconductors (ICDS), July 26th-30th, 20221, Oslo,

189. The Terawatt challenge: The key role of PV monitoring, Anne Gerd Imenes (UiA), NSCC 2022, Son, 2 May 2022.

190. Production estimates for tandem solar cells using high resolution spectral data, Rune Strandberg (UiA), NSCC, Son, 3 May 2022,

191. Pearl PV Country Reports 2020, Chapter for Norway authored by Anne Gerd Imenes, with input from Solenergiklyngen, Multiconsult and others. Published 2022, https://www.pearlpv-cost.eu/pearl-pv-country-reports-2020-download/

192. Review of Global Trends in Agrivoltaic Research & Implementation in Norway, Ronald Reagon R, Erlend Hustad Honningdalsnes, Gaute Stokkan, Steve Völler, Marisa Di Sabatino, NSCC, May 2.-3. 2022. Oral presentation.

193. Hva skjer med solcelleanlegg i Norge om vinteren? Erik Stensrud Marstein, Mari Øgaard, glassogfasade.no, 02.12.2021

194. Hvordan holde solcellepaneler rene og effektive? Erik Stensrud Marstein, Heine Nygard Riise, Josefine Helene Selj. Glassogfasade.no februar 2022

195. Form, farge og tekstur på bygningsintegrerte solcellepaneler, Erik Stensrud Marstein, glassogfasade.no juni 2022

196. Tosidige solcellepaneler – en snarvei til økt virkningsgrad, Erik Stensrud Marstein, glassogfasade.no 04.10.2022

197. Norsk industri har nøkkelen til det grønne skiftet i Europa: Det vet ikke Norske myndigheter, Maja Busch Sevaldsen, Gaute Stokkan, Sean Erik Foss, Trude Nysæter, Morten Meier, Lill Torunn Kjelde, Sverre Myrli, Arendalsuka 16.08.2022

198. Solenergi løser energikrisen - behovet for forskning og utvikling, Gaute Stokkan, Thor-Christian Tuv, Kristin Melsnes, Charly Berthod, Arendalsuka 2022
199. Analysis of Global Trends in Agrivoltaic Research, Ronald Ravi Kumar, Erlend Hustad Honningdalsnes, NSCC 2022, 02.05.2022
200. Performance of ground-mounted Bifacial PV power plants in a Nordic climate, Dina Martinsen, NSCC 2022, 02.05.2022
201. Outdoor photoluminescence imaging based on string inverter's IV curve sweeps, Marija Vukovic, NSCC 2022, 02.05.2022
202. Using raytracing to model energy and crop yield from agrivoltaic greenhouse systems, Taeo Laue, Heine Nygard Riise, Erik Stensrud Marstein, NSCC 2022, 02.05.2022
203. Modelling of bifacial PV-modules using Ray tracing, Mina Elise Holter, NSCC 2022, 02.05.2022
204. Modelling and Testing of Agrivoltaics in Norway, Erlend Hustad Honningdalsnes, Ronald Reagon Ravi, Gaute Stokkan, Marisa Di Sabatino, Steve Völler, NSCC 2022, 02.05.2022
205. Norge - Stolt solnasjon og Industritradisjon, Gaute Stokkan, Arendalsuka 2022
206. Fra "Made in China" til "Made in Europe" - Utviklingen av den europeiske verdikjeden for PV. Hvordan kan Norge bidra, Sean Erik Foss, Arendalsuka 2022
207. En sirkulær og bærekraftig produksjonsprosess, Trude Nysæter, Arendalsuka 2022
208. Norge glemmer sola når vi satser på fornybar energi, E. Melteig, J. Selj, K.Bergum, Podcast universitetsplassen, UiO, 85/2022
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210. Solceller: I dag og i morgen, K. Bergum, Ungforsk 2022
211. Hva er fremtiden i bygningsintegrerte solceller? T. Kolås, Materialforum, online webinar 2022
212. The effect of the hydrogen concentration on boron-oxygen related degradation in silicon wafers, Rune Søndenå, Frank Mosel, Philip M. Weiser, Nicole A□mann, NSCC 2022, May 2nd, 2022, Son
213. Evolution of hydrogen-related impurities in boron-doped Cz-grown silicon wafers during dark annealing, Nicole A□mann,Philip M. Weiser, Rune Søndenå, Frank Mosel, and Edouard Monakhov, Norwegian Solar Cell Conference 2022, May 2nd, 2022, Son
214. Designing materials for tandem solar cells: the case of zinc oxynitride, K. Bergum, NSCC 2022
215. Processing and refining routes for secondary raw materials from silicon ingot and wafer manufacturing for high-end markets (ICARUS), Birgit Ryningen et al., NSCC 2022, May 2nd, 2022, Son
216. Nytt FME-senter innen solkraft, Erik S. Marstein, 14/11 – 2022. Solenergiklyngens partnersamling
217. Experience from two research centers in PV technology, Erik S. Marstein, 15/11-2022, keynote SOLVE kick-off Karlstad
218. SiH4 production from Mg2Si produced via the magnesiothermic reduction of natural quartz, Azam Rasouli, NSCC 2022
219. Recovery of Si from EoL-Si cells by vacuum refining approach, Arman Hoseinpur, NSCC 2022
220. Sustainable silicon production at REC Solar Norway, Tyke Naas, NSCC 2022
221. Solkraft, Invitert foredrag, UD sin seminarserie om EUs grønne giv, Erik S. Marstein, 03.02.2022
222. Solenergi som nøkkel til energisikkerhet, invitert, Sol på en fredag, Solenergiklyngen, Erik S. Marstein 01.04.2022
223. Welcome and introduction, NSSC 2022, Son, Erik S. Marstein 02.05.2022
224. Solkraft, invitert foredrag, ntrans workshop om Energikrisen i Europa, Oslo, Erik S. Marstein 13.05.2022
225. Solar cell technology, foredrag for førsteårsstudentene, UiO, Erik S. Marstein 29.08.2022
226. Welcome and introduction, FME SUSOLTECH Annual Meeting, Erik S. Marstein 29.08.2022

227. The effect of sand type on the OH-content and distribution in fused quartz crucibles, Gabriela Kazimiera Warden, Mari Juel, Bartlomiej Adam Gawel, Marisa Di Sabatino, Nasjonal konferanse for materialteknologi, 1.06-2.06.2022

228. Forskning og teknologiutvikling i solcelleverden, Per-Anders Hansen, NTVA / Polyteknisk forening, 23. feb 2023, Oral presentation.

229. Reducing Time and Costs of FT-IR Studies of Hydrogen Species in Si Wafers and Solar Cell Structures, Nicole Aßmann, Rune Søndernå, Benjamin Hammann, Eduard Monakhov, NSCC 2023, Mai 2023. Son Norway, Oral presentation

230. Surface Examination of Structurel Loss in N-type Czochralski Silicon Ingots, Rania Hendawi, Eivind, Øvrelid, Gaute Stokkan, Marisa Di Sabationo, NSCC 2023, Mai 2023. Son Norway, Oral presentation

231. Investigation of Hydroxyl (OH) Groups Uniformity in Fused Quartz Crucibles Used for Czochralski Silicon Production, Gabriela Kazimiera Warden, Petra Ebbinghaus, Martin Rabe, Mari Juel, Bartłomiej Adam Gaweł, Andreas Erbe, Marisa Di Sabatino, NSCC 2023, Mai 2023. Son Norway, Oral presentation

232. Investigation of process parameters on the distribution of the specific resitivity in Ga-doped Cz-crystal, Frank Mosel, NSCC 2023, Mai 2023. Son Norway, Oral presentation

233. Marhine Learning Methods for Structure Loss Classification in Czochralski Silicon Ingots, Alfredo Sanchez Garcia, Rania Hendawi, NSCC 2023, Mai 2023. Son Norway, Oral presentation

234. Plasma enehanced ALD of thin passivation layers for silicon solar cells, Per-Anders Hansen, NSCC 2023, Mai 2023. Son Norway, Oral presentation

235. Recent progress in Si films deposited by high-rate electron beam deposition, Marit Stange, Tor Olav Sunde, Runar Dahl-Hansen, Alexander Ulyashin, Alexander Azarov, NSCC 2023, Mai 2023. Son Norway, Poster presentation

236. Method Development for Temperature Dependent Lifetime Spectroscopy, Vilma Kristiansson, Alfredo Sanchez Garcia, Marisa Di Sabatino, NSCC 2023, Mai 2023. Son Norway, Poster presentation

237. Synthesis of Mg2Si and its use for silane production, Azam Rasouli, Annual meeting FME Susoltech 2023, 24th May 2023, Son Norway

238. What do we know about quartz crucibles now? A summary of my PhD-project, Gabriela Kazimiera Warden, Annual meeting FME Susoltech 2023, 24th May 2023, Son Norway

239. Structure loss in Cz-Si, Rania Hendawi, Annual meeting FME Susoltech 2023, 24th May 2023, Son Norway

240. Optimizing electrical properties of ZnON for Si-tandems, Kjetil Karlsen, Annual meeting FME Susoltech 2023, 24th May 2023, Son Norway

241. Colored PV modules based on optical interference coatings, Tore Kolås, Annual meeting FME Susoltech 2023, 24th May 2023, Son Norway

242. A comparative Study of Marchine Learning Techniques for Bifacial Photovoltaic Power Forcasting, Alfredo Sanchez Garcia, Mina Elise Holter, NSCC 2023, Mai 2023. Son Norway, Poster presentation

243. Predicting and optimising the performance of coloured solar cell modules based on interference coatings, Tore Kolås, Arne Røyset, Ørnulf Nordseth, Chang Chuan You, NSCC 2023, Mai 2023. Son

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245. Appearance and efficiency in building integrated photovoltaics, Arne Røyset, Tore Kolås, Presentation at NETApp Workshop on Material Appearance, Gjøvik, Norway, November 22nd, 2023

246. Combinatorial pulsed laser deposition, Hogne Lysne, Thomas Brakstad and Turid Reenaas, NSCC 2023, Mai 2023. Son Norway

247. Welcome and Status, Erik S. Marstein, NSCC 2023, 22. Mai 2023. Son

248. Characterization and leaching purification of industrial Si-kef, Tinotenda Mubaiwa, NSCC 2023, 22. Mai 2023. Son

249. Investigation of silane gas production through Mg2Si reaction with HCl acid solution, Azam Rasouli, NSCC 2023, 22. Mai 2023. Son

250. Numerical device simulations of ZnOxNy for Si-based tandem solar cells using Silvaco Atlas, Ingvild Bergsbak, NSCC 2023, 22. Mai 2023. Son
251. The effect of annealing on ZnON for solar cell applications, Kjetil Karlsen, NSCC 2023, 22. Mai 2023. Son
252. Analysis of the theoretical PV power potential on buildings in Norway, Stine Fleischer Myhre, NSCC 2023, 23. Mai 2023. Son
253. Extraction of photoluminescence with Pearson correlation coefficient from images of field-installed photovoltaic modules, Marija Vukovic, NSCC 2023, 23. Mai 2023. Son
254. Assessing the potential for PV snow mitigations to increase PV deployment on existing building roofs, Iver Frimannslund, NSCC 2023, 23. Mai 2023. Son
255. The Effect of PV Panels on Microclimatic Growth Conditions and Crop Yield in Agrivoltaic Systems, Erlend Hustad Honningdalsnes, NSCC 2023, 23. Mai 2023. Son
256. Photoluminescence imaging from the rear of bifacial solar modules in both diffuse and direct sunlight, Mirabai Hillestad, Marija Vukovic, Marko Jakovljevic, Ingunn Burud, Espen Olsen, NSCC 2023, 22. Mai 2023. Son, Poster
257. Analysis of which factors make PID more visible in ΔPL images and the trends between them, Mathea Salmi Marjavara, Marija Vuković, Ingunn Burud, Gisele A. dos Reis Benatto, Rodrigo Del Prado Santamaría, Sergiu V. Spataru and Espen Olsen, NSCC 2023, 22. Mai 2023. Son, Poster
258. Method Development for Temperature Dependent Lifetime Spectroscopy, Vilma Kristiansson, Alfredo Sanchez Garcia, Marisa Di Sabatino (NTNU/SINTEF), NSCC 2023, 22. Mai 2023. Son, Poster
259. Energikrisen i Europa og det norske kraftmarkedet, Tomasgard, M. Belsnes, M. Bjørndal, A. Elverhøi, K. Espegren, T. Fæhn, S. Jaehnert, G. Kjølle, M. Korpås, E.S. Marstein, P. Røkke, N.H. Sandberg, J.O.G. Tande, T.K. Thiis, T. Winther og T.H.J. Inderberg, Asgeir Tomasgard (NTNU, redaktør) energikrisen-i-europa-og-det-norske-kraftmarkedet.pdf (uio.no) Januar 2023
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261. Nye utviklinger i solkraftindustrien, Solceller på Kommunale tak (NVE), Oslo/nett , Erik Stensrud Marstein, 17. februar 2023
262. Hva er framtidsmulighetene med solkraft på Vestlandet, Solkonferanse, Stord/nett, Erik Stensrud Marstein, 21. mars 2023
263. Solkraft – en oppdatering, Faglunsj, Olje- og Energidepartementet, Erik Stensrud Marstein, 29. mars 2023.
264. Solkraft, Innlandets Ingeniørkonferanse, Erik Stensrud Marstein NITO, Gjøvik, 21. april 2023
265. Muligheter og utfordringer for utbygging av solkraftverk i norske bygninger, Erik Stensrud Marstein, Tekna lunsjmøte 27. april 2023
266. Welcome and introduction, Erik Stensrud Marstein, FME SUSOLTECH Annual Meeting, Son 24. Mai 2023
267. The status of the PV industry, Erik Stensrud Marstein, Solenergiklyngens strategisamling, 12. oktober 2023
268. Mot et nytt veikart for den norske solbransjen, Erik Stensrud Marstein, Bygg Reis Deg , Lillestrøm, 18. oktober 2023
269. Bygningsintegrerte solceller på Bygg reis deg, Erik Stensrud Marstein, NTL info, 18. oktober 2023
270. Welcome and Status of the PV industry in Norway, Erik S. Marstein, NSCC 2024, Son 6.-7. Mai 2024
271. Opportunities and challenges related to Solar Power in Norway, Anneline M. Breen, NSCC 2024, Son 6.-7. Mai 2024
272. PVGIS or Meteonorm? Validation of six irradiance products in Norway, Heine Nygård Riise, NSCC 2024,
273. Evaluation of irradiance decomposition and transposition models for Nordic Mountain areas, Dina Martinsen, NSCC 2024
274. Evaluation of the impact of local sensing data and feature extraction techniques on high frequency intra-hour irradiance forecasting, Erling W. Eriksen, NSCC 2024, Son 6.-7. Mai
275. Comparing measured to modelled spectral irradiance for energy yield assessments of tandem PV modules, Erlend Kringlebotten, NSCC 2024, Son 6.-7. Mai

276. Solar sharing at Skjetlein VGS: Norway's first agrivoltaic pilot – first results from co-harvesting grass and electric energy, Gaute Stokkan, NSCC 2024, Son 6.-7. Mai
277. Harvesting the Sun Twice: Agrivoltaic solar application for electricity generation and food production in East Africa, Richard J. Randle-Boggis, NSCC 2024, Son 6.-7. Mai
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280. Status and plans for PV systems in Oslobygg, Ingeborg E. Høiaas, NSCC 2024, Son 6.-7. Mai
281. Bifacial PV Performance in High Latitudes: Experimental Insight into Alpha Centauri Field Laboratory, Berhane Darsene Dimd, NSCC 2024, Son 6.-7. Mai
282. Degradation rates of PV modules in Norway, Christoph Seiffert, NSCC 2024, Son 6.-7. Mai
283. Exploring perovskite nickelates for photovoltaic applications, Anjali Choubey, NSCC 2024, Son 6.-7. Mai
284. Bandgap optimization for colored intermediate band solar cells, Astrid Stokkeland, NSCC 2024, Son 6.-7. Mai
285. Thickness Variation Determination of Perovskite Solar Cells through Hyperspectral Reflectance Imaging, Ivar L. Råheim, NSCC 2024, Son 6.-7. Mai
286. The Quartz Corp - Status and outlook, Christian Hadley, NSCC 2024, Son 6.-7. Mai
287. Metallurgical recycling of kerf loss waste, Tinotenda Mubaiwa, NSCC 2024, Son 6.-7. Mai
288. Influence of aluminium doping on PV properties, Bartlomiej Gawela, NSCC 2024, Son 6.-7. Mai
289. Different Pathways for Mitigating Boron-Oxygen Related Light Induced Degradation in Compensated N-Type Silicon Wafers, Rune Søndenå, NSCC 2024, Son 6.-7. Mai
290. Comparison of FT-IR and 4PP results of Hydrogen complexes in Silicon during Dark Annealing, Nicole Assmann, NSCC 2024, Son 6.-7. Mai
291. Polysilicon passivation - Tunneling oxide routes and annealing conditions effect on passivation, Per-Anders Hansen, NSCC 2024, Son 6.-7. Mai
292. Using Hyperspectral Photoluminescence Imaging to Study Phase Segregation in Lead Halide Perovskite Solar Cells, Håkon Holte, Ivar Loland Råheim, Ingunn Burud and Espen Olsen, NSCC 2024, Son 6.-7. Mai
293. Optimizing Bifacial photovoltaic simulations using raytracing in Rhinoceros 3D, Stein Arne Flasnes Haaland, Arnkell Jonas Petersen, Ingunn Burud and Espen Olsen, NSCC 2024, Son 6.-7. Mai
294. Photoactive Materials Discovery with Pulsed Laser Deposition, Magnus Andreassen, NSCC 2024, Son 6.-7. Mai
295. PV System with Thermal Energy Storage (TES) for Norwegian Off-grid Cabins (Hytte), Mulu Bayray Kahsay, Steve Voller, NSCC 2024, Son 6.-7. Mai
296. Comparative Analysis of Deep Learning- Based Solar Irradiance Decomposition Models in High Latitude Regions, Alfredo Sanchez Garcia, Berhane Darsene Dimd, NSCC 2024, Son 6.-7. Mai
297. Ellipsometry mapping for high through-put material exploration, Per-Anders Hansen, NSCC 2024, Son 6.-7. Mai
298. Composition-tunable Optical and Electrical Properties of II-IV-nitrides for Photovoltaic Absorbing Layers, S. B. Kjeldby, D. M. Nielsen, S. Cooil, Y. K. Frodason, E. Zacharaki, I.-H. Lee, A. Kuznetsov, L. Vines, V. S. Olsen, NSCC 2024, Son 6.-7. Mai
299. Snow Impact on PV Performance in Norway: Review and Investigation Towards Novel System Design, Orientations, Dounia Dahlioui, Anne Gerd Imenes, NSCC 2024, Son 6.-7. Mai
300. Structure loss in Czochralski silicon ingots- case study of a particle hit, Amanda Andersson Lindholm, Rania Hendawi, Hendrik Schön, Marisa Di Sabatino, NSCC 2024, Son 6.-7. Mai
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323. Water Reduction Potential for Olive Orchards within AgriPV Systems in Southern Italy, Milani, Simone; Marstein, Erik Stensrud; Honningdalsnes, Erlend Hustad; Riise, Heine Nygard, 2024
324. Solar Fields: Where Energy Meets Agriculture, Honningdalsnes, Erlend Hustad, 2024
325. Modelling and validation of crop yields in Nordic vertical solar parks, Erlend Hustad Honningdalsnes, Norwegian Solar Cell Conference 2025
326. Thin film top cell absorbers for multijunction solar cells, Snorre Kjeldby, NSCC 2025
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80. Understanding and improving fused quartz crucible properties for the silicon solar cell market, M. Di Sabatino, G.K. Warden, M. Juel, INVITED KEYNOTE, CSSC-12, China 28.-30.5.2024

81. Reducing the Angular Colour Dependence of Building Integrated Photovoltaic Modules Based on Optical Interference Coatings, Chang Chuan You, Ørnulf Nordseth, Arne Røyset, Tore Kolås, EU PVSEC 2024 Proceedings; DOI:10.4229/EUPVSEC2024/4BV.4.3, p 20363, 2024, 3-936338-90-6

82. Reducing the angular colour dependence of building integrated photovoltaic modules bases on optical interference coatings, Chang Chuan You, Ørnulf Nordseth, Arne Røyset, Tore Kolås, EUPVSEC 2024, Poster, 23-27.09, 2024

83. Hyperspectral characterisation of perovskite solar cells, Ivar Loland Råheim, Espen Olsen, EUPVSEC 2024, Poster, 23-27.09, 2024

84. Metallurgical recycling of Silicon kerf loss, T.Mubaiwa, poster EUPVSEC, 23-27.09, 2024

85. Thermal stability of double-layer g/b Ga2O3 structures fabricated by ion beams, A. Azarov, A. Galeckas, I. Cora, Z. Fogarassy, V. Venkatachalapathy, E. Monakhov, and A. Kuznetsov, IBMM 2024, talk, 01-05.07,2024, London, UK

86. Self-assembling of Ga2O3 polymorphic heterostructures with ion beams, A. Azarov, CMD31, invited talk, 02-06.2024. Braga, Portugal.

87. Microclimate and Biodiversity Measurements in Norway's first East-West Tilted Agrivoltaic System, Erlend Hustad Honningdalsnes, Erik Stensrud Marstein, Anne Catriona Mehlhoop, Astrid Brekke Skrindo, Heidi Solstad, Heine Nygard Riise, 42nd European Photovoltaic Solar Energy Conference and Exhibition, 2025

88. Analyzing and Modeling Snow Loss in Ground-Mounted PV Systems, Mari B. Øgaard, Erling W. Eriksen, Sigrid Rønneberg, Heine N. Riise, 42nd European Photovoltaic Solar Energy Conference and Exhibition, 2025

89. Detailed Characterization of ZnSnxGe1-xN2 thin films for top-cell absorbers in tandem solar cells, Snorre Braathen Kjeldby, Vegard Standeren Olsen, Dina Marie Nielsen, Ymir Kalmann Frodason, Simon Phillip Cooil, Lasse Vines, Eduard Monakhov, Kristin Bergum, 42nd European Photovoltaic Solar Energy Conference and Exhibition, 2025

90. Applying Machine-Learning Algorithms to Hyperspectral Photoluminescence Images of Perovskite Solar Cells for Enhanced Information Extraction, Ivar Loland Råheim, Håkon Holte, Ingunn Burud, Espen Olsen, 42nd European Photovoltaic Solar Energy Conference and Exhibition, 2025

91. Observation of an Injection Dependent Lifetime Effect in Highly Hydrogenated Boron Doped Wafers, Rune Søndenå, Nicole Aßmann, Frank Mosel, Per-Anders Hansen, SiliconPV 2025, 15th International Conference on Crystalline Silicon Photovoltaics, Oxford, United Kingdom

92. Correlating Structure Loss and Operational Conditions in Czochralski Silicon Ingot Growth using Machine Learning, Garcia A. S., Hendawi, R., Schoen H., and Di Sabatino M., SiliconPV 2025, 15th International Conference on Crystalline Silicon Photovoltaics, Oxford, United Kingdom

93. Fused quartz crucibles for PV applications: the role of Czochralski process parameters and sand quality on the bubble formation and growth, Marisa Di Sabatino, Sebastian H. Hansen, Gabriela K. Warden, Bartlomiej A. Gawel, Mari Juel, SiliconPV 2025, 15th International Conference on Crystalline Silicon Photovoltaics, Oxford, United Kingdom

94. Polysilicon Passivation – Tunneling Oxide Routes and Annealing Conditions Effect on Passivation, Per-Anders Hansen, Junjie Zhu, Rune Søndenå, 1st EU PVSEC, 2024, Vienna, Austria, 10.4229/EUPVSEC2024/1CV.2.7

The activities have resulted in the following reports, lecture, presentation at technical meetings:

1. Green PV coatings for the Ticon façade, Junjie Zhu, Josefine Selj, IFE/KR/F-2018/009

2. Literature review on diamond wire sawing for high performance multicrystalline silicon, Birgit Ryningen, (SINTEF report)

3. Solar silicon production by mectallurgical processes, Jafar Safarian, Meeting with University of Tokyo, 2019

4. Solar research in FME-SUSOLTECH, Jafar Safarian, Meeting with Xiamen University, 2019

5. Enhanced phosphorus separation from acid leaching of Mg alloyed metallurgical-grade silicon, Mengyi Zhu, NTNU 15/11 2019

6. Li Doped DC Magnetron Sputtered Cu2O Thin Films, M. Nyborg, K. Bergum, E. Monakhov, Nordic Nanolab user meeting (NNUM), Poster 2019

7. Outdoor PV performance monitoring: Results from UiA, Grimstad, Basant R Paudyal, FME SUSOLTEH Annual Meeting 2020.

8. Outdoor fault detection in old photovoltaic solar modules, Oscar K Segbefia, FME SUSOLTEH Annual Meeting 2020.

9. Norway country report" to the PEARL-PV, A. G Imenes, submission of report to the PEARL-PV committee, 2020 (to be published).

10. Embedded Organics in Crystalline Fluorides, Per-Anders Hansen, Oral Presentation ALD/ALE2020

11. Quinizarin: A Large Aromatic Molecule Ideal for Atomic Layer Deposition, Per-Anders Hansen, Poster, ALD/ALE2020

12. Detecting hydrogen-related defects using IR spectroscopy in commercially-available silicon wafers, Philip M. Weiser, Eduard Monakhov, Halvard Haug, Marie Syre Wiig, and Rune Søndenå, FME SUSOLTECH Annual Meeting 2020
13. Aesthetic Evaluation Criteria for Façade Integrated PVs in Urban Context, Changying Xiang, Barbara Szybinska Matusiak, Claudia Moscoso, Report, FME SUSOLTECH Annual Meeting 2020
14. Coloured, transparent and pixelated BiPV, Tore Kolås, Arne Røyset, FME SUSOLTECH Annual Meeting 2020
15. Tandem solar cells and acceptor levels in Cu2O, Martin Nyborg, FME SUSOLTECH Annual Meeting 2020
16. Lanthanide-based thin films for light conversion, Vegard Rønning, FME SUSOLTECH Annual Meeting 2020
17. The effect of Ti and Y addition on the microstructure and leaching purification of Ca alloyed metallurgical silicon, Mengyi Zhu, Jafar Safarian, Silicon for the chemical and solar industry XV, Trondheim, Norway, June 15-18, June 2020
18. Phosphorus and Boron removal from Si by vacuum and gas refining processes, Arman Hoseinpur, Gabriella Tranell, Jafar Safarian, Trondheim, Norway, June 15-18, June 2020
19. Characterization of quartz crucibles used in industrial scale test for production of Cz-Si, Marisa Di Sabatino, Thorleif Stensvold, Daniel Cheung, Yu Hu, Mari Juel, John Atle Bones, FME SUSOLTECH Annual Meeting 2020
20. In-situ observations of dislocations during directional solidification, Gaute Stokkan, Maria Tsoutsouva, Birgit Ryningen, Pål Tetlie, Nathalie Mangelinck Noel, FME SUSOLTECH Annual Meeting 2020
21. High Rate Deposition of Epitaxial Silicon by E-beam, Marit Stange, Tor Olav Sunde, Runar Dahl-Hansen, Amin S. Azar, Joachim S. Graff, Alexander Ulyashin, FME SUSOLTECH Annual Meeting 2020
22. Sustainable production of high silicon material in Norway, Carsten Rohr, FME SUSOLTECH Annual Meeting 2020
23. Sustainable production of high silicon material in Norway, Olav Holta, FME SUSOLTECH Annual Meeting 2020
24. Si purification by acid leaching and slag refining at NTNU Recent activities and outlook, Mengyi Zhu, FME SUSOLTECH Annual Meeting 2020
25. Thermodynamics of Si Ca Mg P for Si dephosphorization, Kai Tang, FME SUSOLTECH Annual Meeting 2020
26. Mechanism of magnesiothermic reduction of SiO2, Azam Rasouli, FME SUSOLTECH Annual Meeting 2020
27. Kinetics of gas phase silane pyrolysis; focus on disilane , trisilane and tetrasilane , Anjitha Geetha, FME SUSOLTECH Annual Meeting 2020
28. Characterization of segregated impurities by 2D and 3D SIMS, Alaxander Azarov, FME SUSOLTECH Annual Meeting 2020
29. Sustainability transitions and solar PV, Dimitra Chasanidou, FME SUSOLTECH Annual Meeting 2020
30. Outdoor Photoluminescence Imaging, Maria Vukovic, FME SUSOLTECH Annual Meeting 2020
31. PV System Degradation Rates in the Nordics, Eivind B. Sveen, FME SUSOLTECH Annual Meeting 2020
32. Thermodynamics of the Si-Ca-Mg-P system for Si dephosphorization, Kai Tang, Trondheim, Norway, June 15-18, June 2020
33. Experimental investigations of monosilane pyrolysis: The importance of cyclic silanes, Guro M. Wyller, Thomas J. Preston, Marte O. Skare, Hallgeir Klette, Anjitha S.G, Erik S. Marstein, Silicon for the Chemical and Solar Industry XV, Trondheim, Norway, June 15 – 18, 2020
34. Solar silicon production by metallurgical processes, Jafar Safarian, For Max-planck Institute, https://www.mpie.de/4631747/jafar_safarian 2021
35. Performance of BIPV and BAPV systems in Norway: Experiences and results from the BIPVNO project", Anne Gerd Imenes, SUSOLTECH combined WP3 & WP4 meeting (Teams online), 03.05.2021.

36. PV Systems Research at University of Agder, Anne Gerd Imenes, SUSOLTECH WP4 seminar (Teams online), 16.06.2021.

37. Imaging for PV module monitoring, O. S. Kwame, SUSOLTECH WP4 online workshop at NMBU, 23 Sept 2021.

38. Facade integrated PVs for high-rise building with balconies, balancing aesthetic, daylight and energy production, C.Xiang, WP3/WP4 seminar series

39. Dominant defect complexes of Cu2O, M. Nyborg, WP3/WP4 seminar series

40. TEM characterization of intermediate band materials, Andreas Rosnes, Hogne Lysne, Thomas Brakstad, Håkon Ånes, Emil Christiansen, Turid Reenaas, Randi Holmestad, WP3/WP4 seminar series

41. Outdoor photoluminescence imaging of silicon modules, M. Vukovic, WP3/WP4 seminar series

42. From PV module faults detected by infrared thermography to string-level power loss, B. Aarseth, WP3/WP4 seminar series

43. An integrated software package for autonomous aerial monitoring of large scale PV plants, M. Aghaei, WP3/WP4 seminar series

44. Colored PV modules based on optical interference coatings, Ø. Nordseth, Susoltech FME annual meeting, 30.08.2022

45. Perovskite solar cells: current status and future prospects, I.L Råheim, Susoltech FME annual meeting, 30.08.2022

46. Update WP3, K. Bergum, Susoltech FME annual meeting, 30.08.2022

47. Results from work in 2022, T. Kolås, A. Røyset, WP3 meeting. oct '22

48. Update 2022 and plans for 2023/IFE, Ø. Nordseth, WP3 meeting, oct 2022

49. Update work 2022, FiPV, C.Xiang, WP3 meeting, oct 2022

50. Update 2022 and plans for 2023/NMBU, perovskites, E. Olsen, WP3 meeting, oct 2022

51. Update 2022 and plans for 2023\UiO, photon conversion, P-A. Hansen, WP3 meeting, oct 2022

52. Update 2022 and plans for 2023/NTNU, Intermediate band, T. Reenaas, WP3 meeting, oct 2022

53. Update 2022 and plans for 2023, UiO, tandem, K. Bergum, WP3 meeting, oct 2022

54. Processes to recycle Si-kerf (a review), Tinotenda Mubaiwa, Seminar on refining and recycling of solar silicon, Trondheim, 04/11/2022

55. Recycling of PV panels; Cabris and SuperPV EU projects, Alexander Ulyashin, Kai Tang, Armn Hoseinpur, Jafar Safarian, Seminar on refining and recycling of solar silicon, Trondheim, 04/11/2022

56. The World's greenest solar silicon, Erik Enebakk, Seminar on refining and recycling of solar silicon, Trondheim, 04/11/2022

57. Silane production from Mg2Si materials, Azam Rasouli, Webinar series sfi metal production, Trondheim, 17/6/2022

58. Status WP2, Mari Juel, FME Susoltech Annual Meeting 30. August 2022

59. Tracking hydrogen in silicon PV wafers with FT-IR spectroscopy, Nicole Aβmann, PhD, UiO, FME Susoltech Annual Meeting 30. August 2022

60. Silicon Ingot and Wafer Production at NorSun, Hendrik Schön, Norsun, FME Susoltech Annual Meeting 30. August 2022

61. Diamond wire kerf as raw material for SoG-Si, Erik Enebakk, REC Solar, WP1/WP2 meeting Nov 2022

62. Magnesiothermic reduction of quartz and silane production, Azam Rasouli, NTNU WP1/WP2 meeting Nov 2022

63. Characterization and purification of Si-kerf, Tinotenda Mubaiwa and Margrete Johnsson, NTNU WP1/WP2 meeting Nov 2022

64. Application of Machine/Deep Learnings (ML & DL) in representation of the metallothermic reduction of silicon oxide, Kai Tang, SINTEF, WP1/WP2 meeting Nov 2022

65. Ion-beam facilities at UiO: the current status and activity, Alexander Azarov, UiO, WP1/WP2 meeting Nov 2022

66. Tracking hydrogen in silicon PV wafers with FT-IR spectroscopy, Nicole Aβmann, UiO, WP1/WP2 meeting Nov 2022

67. On viscosity, uniformity and cristobalite formation in fused quartz, Gabriela Warden, NTNU, WP1/WP2 meeting Nov 2022

68. Analysis of surface features on structure loss Cz-Si ingots, Rania Hendawi, NTNU, WP1/WP2 meeting Nov 2022

69. Modeling of impurity transport during Cz-pulling, Alfredo Sanchez Garcia, SINTEF, WP1/WP2 meeting Nov 2022

70. Impurity related limitations in PERC/PERT solar cells; A computational study, Rune Søndenå, IFE, WP1/WP2 meeting Nov 2022

71. Er det smart å få solenergi fra fasader og vegger? Webinar, Solenergi FUSen 21.10.2022 Webinaropptak | Er det smart å få solenergi fra fasader og vegger? (fusen.no)

72. CEO Gøran Bye presents at ONS 2022, 7.9.2022 CEO Gøran Bye presents at ONS 2022 (crystals.no)

73. Dark Annealing-Induced Evolution of HB in Silicon: A Comparative Analysis with Resistivity and H2 Concentration, Nicole Aßmann, WP1/WP2 meeting FME Susoltech, 8th November 2023, Trondheim. Norway

74. Evaluation of different passivation shemes, Per-Anders Hansen, WP1/WP2 meeting FME Susoltech, 8th November 2023, Trondheim. Norway

75. On the uniformity (or lack of it) of fused quartz crucibles, Gabriela Kazimiera Warden, WP1/WP2 meeting FME Susoltech, 8th November 2023, Trondheim. Norway

76. Root Cause Analysis for Structure Loss in Cz-Si Growth, Rania Hendawi, WP1/WP2 meeting FME Susoltech, 8th November 2023, Trondheim. Norway

77. Advancing Classification of Structure Loss in Cz Ingots with Machine Learning, WP1/WP2 meeting FME Susoltech, Alfredo Sanchez Garcia, 8th November 2023, Trondheim. Norway

78. Redistribution of hydrogen in Si wafer during Light soaking, N. Aßmann, FME Susoltech WP1/WP2 meeting, 23.10, 2024

79. The effect of hydrogen on the light sensitive born-oxygen effect, R. Søndenå, FME Susoltech WP1/WP2 meeting, 23.10, 2024

80. Fused quartz crucibles for Czochralski silicon production, G. K. Warden, FME Susoltech WP1/WP2 meeting, 23.10, 2024

81. Study of Bubble Growth Inside the Fused Quartz Crucible Under Cz Si Ingot Pulling Conditions Via Heat Treatment, Y. Xu, FME Susoltech WP1/WP2 meeting, 23.10, 2024

82. Nitrogen Behavior in the Cz Process: Challenges of Using Recycled Silicon for Crystal Quality and Solar Cell Manufacturing, B. Ryningen, FME Susoltech WP1/WP2 meeting, 23.10, 2024

83. Epitaxial deposition of silicon with electron beam deposition, M. Stange, FME Susoltech WP1/WP2 meeting, 23.10, 2024

84. The solar revolution, Erik S. Marstein, The future of energy is green and digital, 10.01.2024. UiO

85. Solar power (PV), Erik S. Marstein, Lecture for 1st year UiO students, Sundvollen, 02.09.2024

86. R&D in the PV industry, Erik S. Marstein, SINTEF PV group meeting 21.10.2024

87. Hydrogen Related Complexes in SolarCell Silcicon, N. Aßmann, Presentation, 22.05.2024
88. The unfinished Manuscript - about the art of (not) letting go, N. Aßmann, Internal LENS seminar, 02.02.2024
89. Fourier Transform Infrared Spectroscopy, N. Aßmann, NNUM 2024, poster, 03.-04.06.2024
90. Carbon footprint optimization applied to utility scale projects. Report FME SUSOLTECH Partners, (Unni Musdalslien, Equinor 2020)
91. Solar PV circularity update 2023, Report FME SUSOLTECH Partners, (Jørn Paus, Equinor 2023)
92. Silicon recovery from kerf loss waste, T.Mubaiwa, CRU Silicon Market Forum 2024, 12.09.2024
93. Metallurgical Recycling of Silicon Kerf, T.Mubaiwa, HyProS seminar, 05.11.2024

The activities have resulted in the following communication effort for relevant target group:

1. Pågående forskning på framtidas solceller, School wisit from highshool students, Presentation and lab tour. Hogne Lysne and Turid Reenaas.2018
2. Pågående forskning på framtidas solceller, Part of ”Åpen dag/Open day” at NTNU. Presentation for high school students in lab. Hogne Lysne and Turid Reenaas 2018
3. Dynatec Presentasjon for Mulighetsriket journalist, Rune Holter, Dynatec Askim, 12. januar 2018
4. Dynatec Presentasjon for Østfold Fylkeskommune til brosjyre, Rune Holter, Dynatec Askim, 15. Januar 2018
5. Dynatec Nettverk for Askimbyen AS, Rune Holter, Dynatec Askim, 15. februar 2018
6. Dynatec presentasjon for Askim Næringsutvikling, Rune Holter, Dynatec Askim, 1. mars 2018
7. Dynatec Presentasjon for Mulighetsriket Østfold ambasadører, Rune Holter, Dynatec Askim 1.juni 2018
8. The Explorer, Per A. Lilleng Innovasjon Norge, Østfold, 3-4. juni. 2018
9. Dynatec presentasjon for Askim borgere, Rune Holter, Dynatec Askim, 20. juni 2018
10. Dynatec samarbeid skole og lærlinger for Yrkesopplæringsnemda Østfold, Rune Holter, Dynatec Askim, 6. september 2018
11. Dynatec presentasjon Erasmus+ for lærere fra Østerrike og Tsjekkia, Rune Holter, Dynatec Askim, 10. september 2018
12. Dynatec presentasjon for VGS elever fysikk Askim og Mysen VGS, Rune Holter, Dynatec Askim, 17. september 2018
13. Dynatec Holdninger, utdanning og lærlinger for ungdomsskole rådgivere, Rune Holter, Dynatec Askim, 28. September 2018
14. Dynatec Holdninger, utdanning og lærlinger for Askim Næringslivledere, Rune Holter, Bystyresalen Askim, 24. oktober 2018
15. Dynatec presentasjon for Presseveteranene i Østfold, Rune Holter, Dynatec Askim, 29. oktober 2018
16. Dynatec presentasjon for KRF Østfold, Rune Holter, Dynatec Askim, 29. oktober 2018
17. Dynatec Holdninger, utdanning og lærlinger for OKI Østfold og fagledere TIP Østfold, Rune Holter, Dynatec SMV, 2. november 2018
18. Dynatec Holdninger, utdanning og lærlinger for alle TIP lærere i Østfold, Rune Holter, Glemmen VGS, 12. november 2018
19. Morgendagens solceller – utstyr og materialer, Hogne Lysne, Abel-finalen, omvisning på Institutt for fysikk, 6. mars 2019, https://abelkonkurransen.no/nb/
20. Morgendagens solceller – utstyr og materialer, Hogne Lysne, Åpen dag på NTNU, 20. mars 2019, https://www.ntnu.no/moetntnu/apendag
21. Kunnskapsløftet - fra kvantesprang til fotballtipping, Hogne Lysne, Teknologiuka for jenter 2019, 8. og 9. november 2019, https://www.ntnu.no/jenter/teknologiuka
22. Ode til Silisum, Halvard Haug, Forskningsdagene, Science Slam 2019

23. Spectral Measurements in the Nordics" during parallel workshop session S5, A.G. Imenes, Presentation, Assessment of spectral irradiance differences" at the PEARL-PV meeting in Utrecht 26/2 2020.
24. Solar silicon production by metallurgical route, Jafar Safarian, Meeting with researchers at Jülich Research Centre, 2020
25. Veikart for den norske solbransjen mot 2030, Erik S. Marstein, foredrag ved Solenergiklyngens kick-off, Oscarsborg 15/1-2020
26. Solceller, Erik S. Marstein, foredrag ved Naturfagssenterets seminar for Lektor 2, Lillestrøm 30/1-2020
27. Et veikart for den norske solbransjen mot 2030, foredrag ved International Solar Day, Norwep, 26/5-2020
28. Welcome and introduction, foredrag ved FME SUSOLTECH's årsmøte 19/8 (zoom) 2020
29. Solar cell technology,, Erik S. Marstein, foredrag ved NORRENs sommerskole 20/8 (zoom)-2020
30. Digitalization of solar power,, Erik S. Marstein, foredrag ved Norsk Regnesentral 24/9-2020
31. Veikart for den norske solbransjen mot 2030, Erik S. Marstein,foredrag ved Solenergiklyngens Clean Tuesday 27/10-2020
32. Solkraft – på rask vei mot toppen, Erik S. Marstein foredrag for Tekna 28/10-2020
33. Teknologiutvikling innen solkraft, Erik S. Marstein foredrag for Teknas Fagdag 2/11 2020
34. Bygningsintegrerte solcellepaneler - Hvordan redde verden på en vakker måte, blogg-post by Erik S. Marstein on Fusen.no 30/6 2020
35. UiA PV system represented in SUSOLTECH PV map / IDIUM database, https://susoltech.no/solarpanelmap/uia-grimstad/
36. Detecting hydrogen impurities in multicrystalline silicon wafers, Philip M. Weiser, https://susoltech.no/detecting-hydrogen-impurities-in-multicrystalline-silicon-wafers/
37. Simulation of 12 different BIPV façades for Voldsløkka skole for Oslo Bygg and Veidekke (4 different colours and 3 different types of glass) a.Used for choosing a façade with the optimum combination of esthetics and PV-losses 2021
38. Simulation of different string lengths used on same MPPT and effect on yield. The work is used internally in Fusen for deciding string architecture in actual projects, especially in relation to inverters with only one MPPT. 2021
39. Bønder, produsenter og fiskere må få betalt for å produsere maten mer bærekraftig, Gaute Stokkan, Video, Forlag; Rethink Food, 10 filmer om bærekraftig matproduksjon - Rethink Food
40. Kan sola redde oss fra energikrisen? Anne Gerd Imenes, Lørdagsuniversitet, Arendal, 4 February 2023, arr: Universitetet i Agder
41. Kan sola redde oss fra energikrisen? Anne Gerd Imenes, Solcelledagen 2023, Kristiansand, 16 February 2023, arr: Trade Winds Solar
42. Kan sola redde oss fra energikrisen? Anne Gerd Imenes, Grimstad Rotary Club, Grimstad, 9 March 2023, arr: Grimstad Rotary club
43. Klimakrise og energikrise: Kan sola være løsningen? Anne Gerd Imenes, Klimaseminaret på Dahlske VGS, Grimstad, 7 March 2023, arr: Dahlske skole
44. Klimakrise og energikrise: Kan sola være løsningen? Anne Gerd Imenes, Årsmøte Besteforeldrenes Klimaaksjon, Kristiansand, 28 March 2023, arr: Besteforeldrenes Klimaaksjon
45. Agri-PV, Erlend Hustad Honningdalsnes, Store Norske Leksikon / https://snl.no/agri-PV
46. Soldeling i landbruket, Gaute Stokkan, Erlend Hustad Honningdalsnes m.fl., Skjetlein, 26 Oct 2023
47. Glass & Fasade, UTGITT AV GLASS OG FASADEFORENINGEN // NR 1-2023, Glass & Fasade nr. 1 – 2023 (glassogfasade.no)
48. Glass & Fasade, UTGITT AV GLASS OG FASADEFORENINGEN // NR 2-2023, Glass & Fasade nr. 2 – 2023 (glassogfasade.no)

49. Glass & Fasade, UTGITT AV GLASS OG FASADEFORENINGEN // NR 3-2023, digitalarkiv - Magasinet Glass & Fasade (glassogfasade.no)
50. Glass & Fasade, UTGITT AV GLASS OG FASADEFORENINGEN // NR 4-2023, digitalarkiv - Magasinet Glass & Fasade (glassogfasade.no)
51. Synergier mellom energiproduksjon og naturbevaring, Fagdag for bakkemonterte solkraftverk i regi av Solenergiklyngen, 1. juni 2023
52. What did we achieve?. FME SUSOLTECH Final Conference, Erik S. Marstein, 19.05.2025 Son
53. Hva fikk vi til? Erik S. Marstein, Forskningsrådet, 19/6
54. Sustainable silicon feedstock production, Marisa Di Sabatino, FME SUSOLTECH Final Conference 2025
55. High quality silicon ingots & wafers, Mari Juel, FME SUSOLTECH Final Conference 2025
56. Production of high purity quartz, Christian Hadley, FME SUSOLTECH Final Conference 2025
57. High efficiency solar cells and modules, Eduard Monakhov, FME SUSOLTECH Final Conference 2025
58. Installation of Building-Applied and Building-Integrated PV in Norway, Ana Chagas, FME SUSOLTECH Final Conference 2025
59. Experience from Building-Applied and Building-Integrated PV in Oslo, Bodil Motzke, FME SUSOLTECH Final Conference 2025
60. Architectural integration of PV: Oen – a case study, Bjarne Ringstad, FME SUSOLTECH Final Conference 2025
61. End use and impact of PV, Heine N. Riise, FME SUSOLTECH Final Conference 2025
62. PV in glass and facades, Bjørn Glenn Hansen, FME SUSOLTECH Final Conference 2025
63. Taking a PhD at FME SUSOLTECH, a subjective report, Nicole Assmann, FME SUSOLTECH Final Conference 2025

Scientific/scholarly publications (monograps publications)- Master thesis:

1. Studie av termiske donorer i Czochralski silisium-skiver ved hyperspektral fotoluminescens, Lisa Kvalbein, MSc avhandling, NMBU 11.11.2017
2. Liquinert quartz crucible Removal of OH groups in silica crucibles to reduce wetting between the crucible and the silicon melt, Mathias Strømme, Master thesis 2018
3. Modelling of heat transfer and fluid flow in a silicon melt for the Czochralski process, Stine Linn Skjerven, Master thesis 2018
4. Recycling of Fine Silicon Particles for Solar Grade Silicon Production, Matthew Engel Wermers, Master thesis 2018
5. Effects of Shading on PV Power Production in Norwegian Climates, Carolyn Willems, Master thesis 2018
6. A study of the performance of two wall attached PV systems in a Nordic climate, Linn Tabita Milde, Master thesis 2018
7. Bifacial Solar Cells in Nordic Climate, Siw Anita Hansen, Master thesis 2018
8. Thermal donors in Czochralski silicon wafers investigated by spectral imaging, Malin Helander, Master thesis 2018
9. Power Prediction of Photovoltaic System using Neuyral Network Models. Camilla Lie, M.Sc, UiA https://uia.brage.unit.no/uia-xmlui/handle/11250/2622441?locale-attribute=no 2019
10. Nucleation and Growth of High Performance Multicrystalline Silicon (HPMC-Si) in Si3N4 and SiC Coated Crucibles, Divya Narayanankutty, Master theisis 2019
11. PV Installation System: Analysis of Performance and Degradation Mechanisms, Hailu Asmare Libassie, M.Sc thesis IFE/UiO 2019
12. The performance of household PV systems in Southeastern Norway, Aksel Pettersen, M.Sc thesis,IFE/NMBU 2019
13. Recovery and Utilisation of Kerf Waste from Silicon Wafering Process, Kevin Lim, Master thesis 2018

14. TEM characterization of tungsten implanted silicon - A study of a potential intermediate band solar cell material. Jørgen Sørhaug, Master thesis 2018
15. Hyperspectral photoluminescence of thermal donors in two Czochralski crystals pulled at different velocities, Helene Stalheim, M.Sc, NMBU, May 2019.
16. The Relationship between Hydroxyl Content and Viscosity of Fused Silica for CZocralski Process, T.C. Daniel Cheung, M.Sc, NTNU, June 2019.
17. Temperature and injection dependent photoluminescence imaging of charge carrier lifetime in multicrystalline silicon wafers" Amalie Berg, M.Sc, IFE/UiO, June 2019.
18. Hyperspectral imaging as a tool to study solar induced photoluminescence from PV modules, Ingeborg E. Høiaas, M.Sc, NMBU, May 2019
19. Characterization of Li doped, magnetron sputtered Cu2O thin films, Kjetil Karlsen, M.Sc thesis, UiO, 2019
20. Characterisation of tungsten-doped silicon - An intermediate band material candidate from ion implantation and nanosecond pulsed laser melting, Markus J.B. Ristola, Master thesis 2019
21. Deposition of phase-pure Cu2O by magnetron sputtering, Osama Zariouh, Master thesis 2020
22. Investigation of a PV system using a mathematical model and available data, O.-K. M. Nese, Master thesis, University of Agder, Grimstad, 2020. https://uia.brage.unit.no/uia-xmlui/handle/11250/2679634
23. Influence of random upright pyramid substrate surface texture on the colour appearance of dielectric thin film coated silicon PV, Nathan Roosloot, Master thesis, University of Amsterdam 2020
24. Characterization of Silica Crucibles for the Czochralski process, Thorleif Stensvold, Master thesis, NTNU, 2020
25. Study and Investigations of Oxygen Related Defects in Czochralski silicon ingots, Gabriela Warden, NTNU,2020
26. HiPIMS deposition and characterization of amorphous ZnOxNy for solar cell applications, Elin Dypvik Sørdahl, Master thesis 2020
27. Distribution of Aluminum and Calcium between Silicon and CaO-Al2O3-SiO2 Slags at 1650 °C, Safia Hassan, Master thesis 2020
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29. Numerical device simulations of ZnOxNy for Si-based tandem solar cells using Silvaco Atlas, Ingvil Bergsbak, Master thesis 2021
30. Tosidige solcellemoduler: påvirkningen albedo har på tosidig effektgevinst, Mina Elise Ø. Holter, Master thesis 2021
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32. Simulation of the Impurity Photovoltaic Effect in GaAs Solar Cells, Tore Skauge Bysting, Master thesis 2021
33. Effect of the cooling rate on the removal of impurities from metallurgical-grade silicon alloyed with magnesium. Mochamad Ilham Al Fariesy Irvansyah, Master thesis 2021
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35. IR- og dataanalyse for feildeteksjon og diagnostisering av solcellemoduler, Ranvei Isaksen, Master thesis 2021
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39. Performance assessment and degradation analysis of different grid-connected PV technologies installed in Trondheim, Norway, Ali Haider Raja, Master thesis 2021
40. Surface Characterization of Titanium Dioxide Thin Film, Han Na Choi, Master thesis 2021
41. ZnOxNy as a new material for top cell in tandem solar cells, Magnus Johansen, Master thesis 2019
42. Characterization of TiO2 based thin films using Raman spectroscopy, Herman Solstrand, Master's thesis, NTNU, 2021
43. Comparison of fault-detection methods in photovoltaic modules, Herman Schulze Ljosland, UiA, May 2022.
44. Development of a Gas Analysis Method for Silane Gas, Karl Edvin Herstad, Master thesis 2022
45. Power loss estimation of PV modules through IV-characteristics and image analysis, Øyvind Bjørgum, UiA May 2022.
46. Modeling and Analysis of vertical bifacial agrivoltaic test system at Skjetlein high school, Norway, Ronald Reagon Ravi Kumar, NTNU, 2022
47. Performance Modeling of Bifacial PV Power Plants in a Nordic Climate, Dina Martinsen, NTNU 2022
48. Soiling data in PV plants, Andreas Torp Løkkeberg, MSc-oppgave, NMBU 2022
49. Thermal donors in p-type Cz-Si, David A. Nilssen,MSc-oppgave, NMBU 2022
50. Quinizarin as Organic Sensitizer in LnF3 Thin Films for Photon Upconversion, Erlend North, Master thesis 2022
51. A study of performance and degradation of floating PV in tropical climate, Rugile Balciuanaite, MSc-oppgave, NMBU 2022
52. Forecasting of Photovoltaic Power Production, Thale V. Stefansson, Master thesis 2022
53. Improving Impurity Photovoltaic Solar Cells via Inhomogeneous Doping Concentrations in Proximity to the Depletion Region, Thord Niri Gjesdahl Heggren, Master thesis 2022
54. TEM Study of Cr, N Codoped TiO2 Thin Film; Structural Properties of Continous Compositional Spread Film, Andreas Rosnes, Master's thesis, NTNU 2022
55. Pulsed Laser Deposited TiO2; X-Ray Diffraction and Raman Spectroscopy Studies, Marcus Grand Michaelsen, Master's thesis, NTNU 2022
56. Simulation of the Impurity Photovoltaic Effect in TiO2 Solar Cells Using SCAPS, Stine Evjeberg Hansen, Master's thesis, NTNU 2022
57. Pulsed laser growth of La2NiMnO6 for intermediate band solar cells, Amalie Strømme Falck, Master thesis, NTNU 2022
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61. Energy Yield Analysis and Evaluation of Software Used for Different Configurations of Bifacial Photovoltaic Modules in Trondheim, Norway, Sigrid Otterlei Sunde, Master thesis 2022
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64. Simulation of a vertical bifacial PV system compared to measured values, Amalie Elisabeth Robsahm, Master thesis, NMBU 2023
65. Analysis of an Agrivoltaic System at Skjetlein High School, Norway, Harry Malhi, Master thesis NTNU 2023, NTNU Open: Analysis of an Agrivoltaic System at Skjetlein High School, Norway

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67. Coloured intermediate band solar cells, Joseba Miren Ormaetxea Orobengoa, Master thesis 2023
68. Performance analysis of PV power plants across Norway, Martin Krebs Kristiansen, Master thesis, UiA 2023, no.uia_inspera_143762890_99527950.pdf
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74. Visualization and quantification of PID in solar modules using PL imaging in daylight, Mathea Salmi Marjavara, NMBU Master thesis 2023, no.nmbu_wiseflow_6839571_54592238.pdf
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79. Comparing Measured to Modelled Spectral Irradiance for EY Assessments of Tandem PV Modules, E. Kringlebotten, Master thesis, 2024 NMBU
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91. Copper based oxides for tandem solar cells, Nicolle Tello Diaz, Master thesis, UiO 2025
92. Investigating how bubbles influence the viscosity of high purity quartz crucibles, Even Traagstad Gundersen, Master thesis, NTNU 2025

Scientific/scholarly publications (monograps publications)- /PhD thesis:

1. Hyperspectral Photoluminescence Imaging of Silicon Wafers and Solar Cells, Torbjørn Mehl, PhD thesis 2018
2. Experimental investigations of monosilane pyrolysis, Guro Marie Wyller, p205, 2019, ISSN 1501-7710, Forlag Faculy of Matemathics and Natural Sciences, PhD thesis IFE/UiO
3. Silicon purification by acid leaching and slag refining techniques, PhD thesis, Mengyi Zhu, NTNU 2021
4. Vacuum and Gas Refining of Silicon for Solar Cell Applications, PhD thesis, Arman Hoseinpur Kermani, NTNU 2021
5. Façade Integrated Photovoltaic – Architectural Methods in Urban Contexts, Changying Xiang, PhD thesis at NTNU 2022
6. Dominant Defect Complexes in Cuprous Oxide, Martin Nyborg, PhD thesis at UiO 2022
7. Toward monitoring of photovoltaic power plants with photoluminescence imaging, Vukovic, M, PhD. Thesis, NMBU, Brage NMBU: Toward monitoring of photovoltaic power plants with photoluminescence imaging (unit.no)
8. Solar cell degradation: the role of moisture ingress, Segbefia, O. K., PhD thesis, University of Agder, AURA: Solar cell degradation : the role of moisture ingress (unit.no)
9. Synthesis of Mg2Si and its use for Silane production, Azam Rasouli, PhD Thesis, NTNU, 2023, NTNU Open: Synthesis of Mg2Si and its use for Silane production
10. Assessment of PV performance in Nordic conditions: Investigating the influence of spectral irradiance, Basant Raj Paudyal, UiA 2024, AURA: Assessment of PV performance in Nordic conditions: Investigating the influence of spectral irradiance
11. Design and fabrication of (Cr + N) co-doped TiO2 films with a continuous compositional spread, Hogne Lysne. PhD thesis, NTNU Open: Design and fabrication of (Cr + N) co-doped TiO2 films with a continuous compositional spread
12. Quartz crucibles for Czochralski silicon production, Gabriela Warden, PhD thesis, NTNU 2025

Selected spin-off projects from FME SUSOLTECH

Silicon production & recycling	282341	EngQS – Engineering Quartz Sand for Next Generation Solar Crucibles
	256806	ASICO - Advanced single crystal growth control for high-end photovoltaics
	313872	Giant Single-Crystal technology for Premium solar cells
	309614	Ultra-Sustainable semiconductor Substrates for tomorrow's solar
	282301	Solidification of Unseeded high-PERformance MULTIcrystalline silicon
	268027	CruGenSi – Crucibles for next generation high quality silicon solar cells
	255326	INSIDES – IN-SItu characterization and SImulation of Defect Evolution in Silicon
	280831	DiaMApp – Diamond sawing and surface treatment of high performance multicrystalline silicon wafers for high efficiency solar cell applications
	255003	KerfLessSi
	280909	LetUP – LeTID in multicrystalline PERC cells
	958365	Icarus
	101122332	RETRIEVE
	101122298	QUASAR
	101178331	Circular manufacturing 5.0
PV cells and modules	244031	Building Integrated Photovoltaics for Norway
	272806	Hybrid materials for Si surface passivation and battery applications
	244087	TRAnsition metal and LAnthanide based Luminescent Absorber Layers by Ald
	250678	Development of a new ray model for understanding the coupling between dielectric sphere for photovoltaics with higher efficiency
	320714	SunUP – Solar photochemical H2 production through novel routes
	792245	SUPER PV
	818342	PV Adept
	818009	BE-SMART
End use and impact	267951	RENEWGROWTH – Conditions for Growth in Renewable Energy Industries
	296216	ALSPIN – Automation of field inspection in large scale solar farms
	320750	SUNPOINT – SUn in Norway: POtential and INTegration of the solar energy resource
	344524	PREDICT – Providing Reliability and Degradation sCience for the TW-scale PV industry
	344440	ENVISOL – Considering the Environment and Nature when Building and Operating Ground Mounted Solar Power Plants in Norway

Center partners

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