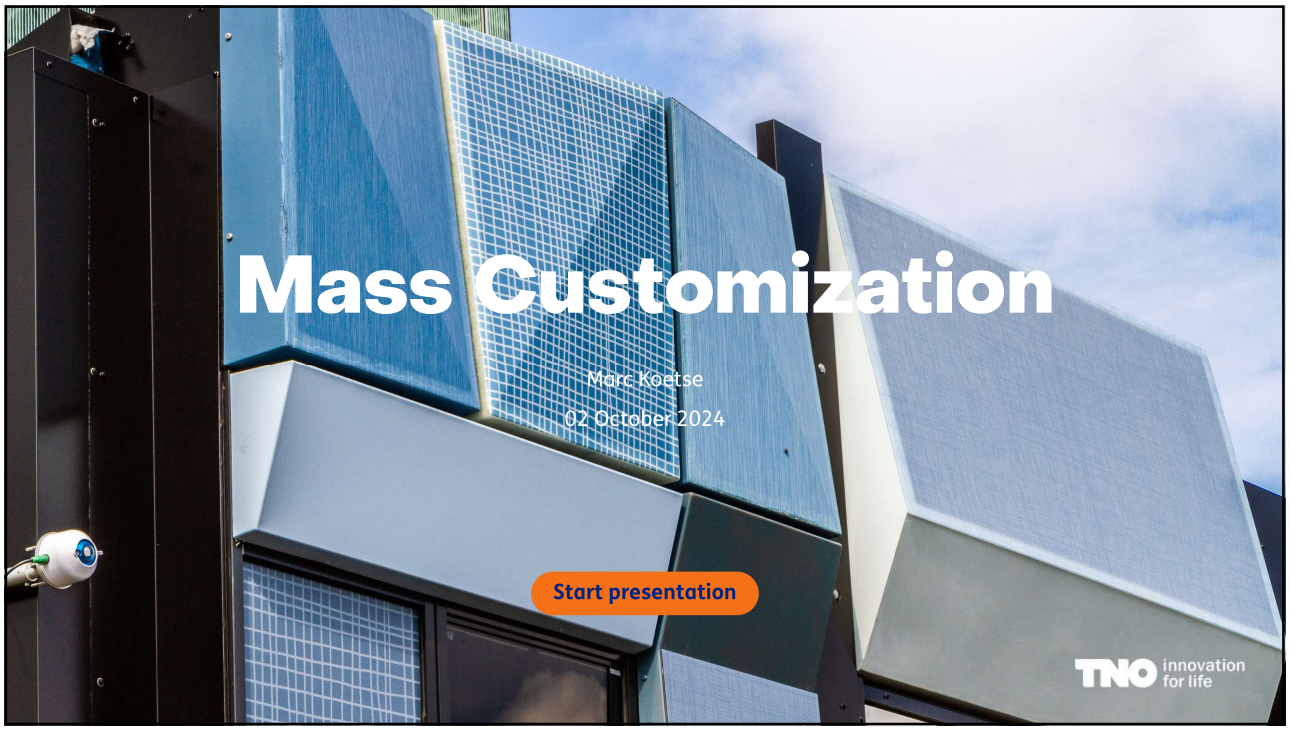

1

Mass Customization

A manufacturing method for integrated solar

Marc Koetse | Stadion Galgenwaard, Utrecht

02 October 2024

2

Climate politics and political quest for energy independence boost PV

- World
  - From 1981 China structural investing in Solar PV development and manufacturing. **Now world leading** in PV manufacturing and national install.
  - 2015. **UN Paris Agreement**. Legally binding international treaty on climate change. Limit the temperature increase to 2°C above pre-industrial levels (and effort to 1,5°C). It defines targets for 2030 and 2050. Nations are called for national plans. Call for renewable energy.
- EU
  - 2019. **EU Green Deal**. The EU aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. Legally binding target via European Climate Law. Call for renewable energy.
  - 2022. Result of energy crisis due to **Russia/Ukraine War**. EU **REPowerEU** package for independence. A roadmap for ending reliance on imported Russian fossil fuels.
  - 2024. **Net Zero Industry Act**. By 2030, the [illegible] sufficient to cover 40% of the EU annual solar deployment.
- Netherlands
  - 2019. **NL Climate Agreement**. > 600 agreements how to reduce emission of greenhouse gasses. Agreements with sectors Build environment, Mobility, Industry, Agriculture, Electricity.
  - 2023. **SolarNL Growth Fund** M€ 412
  - To reach 200 GWp installed by 2050, the net annual installed capacity should increase from 4GWp/year to approximately 10GWp/year by 2040, until 2050.

- **Energy transition**
- **Energy independence**
- **Industrial independence**

PARIS2015 UN CLIMATE CHANGE CONFERENCE COP21·CMP11

European Green Deal

REPowerEU

ESIA European Solar PV Industry Alliance

Klimaatakkoord

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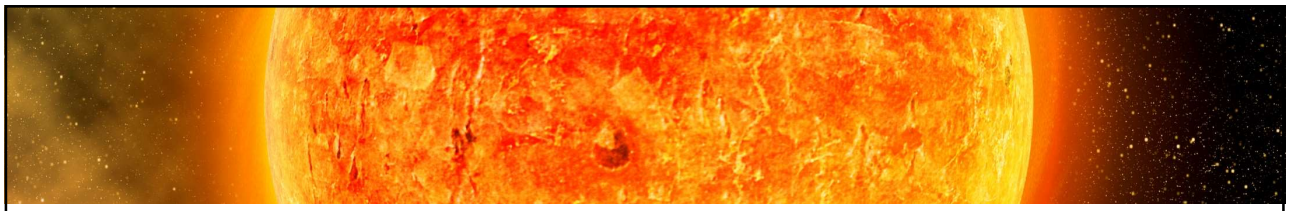


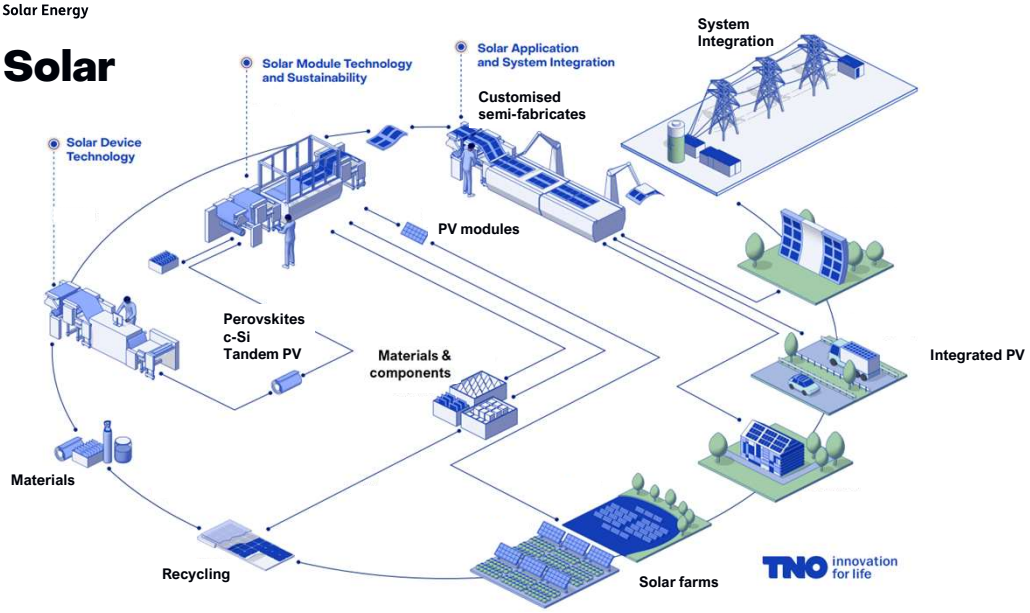
Vision TNO Solar

- In 2050 solar PV is a substantial element of our energy supply
- 200 GWp solar PV will be installed in The Netherlands
  - In such a way that it is **economically affordable**, societal acceptable and with a superior sustainability
  - Besides solar parks on land and water solar energy to a great extend will be **integrated in our environment**
- In this transition, the Dutch solar ecosystem will be optimally positioned for national supply and export

4

Energy Supply Solar Energy

TNO Solar



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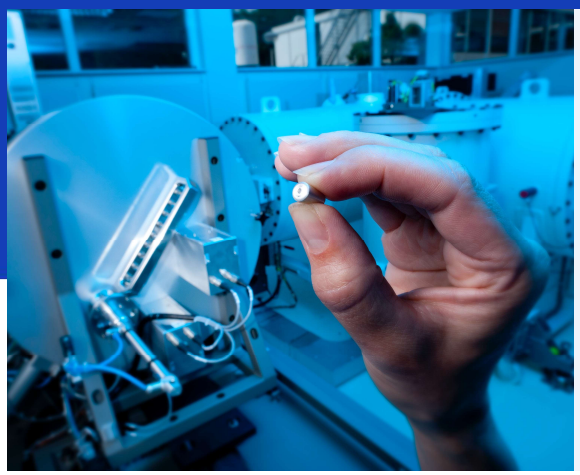
Agenda



1. Why PV-integration
2. What is mass customisation for PV
3. How is Mass customisation for PV implemented
4. What are our plans for the future

6

Funding

MC2.0
Funded by the European Union

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PV-Integration

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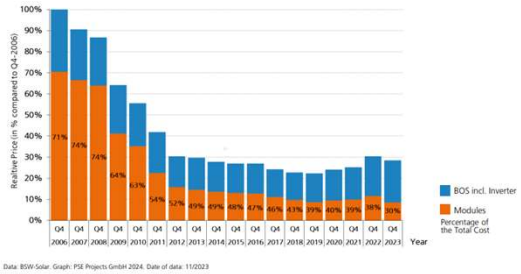
Integrated PV

- Make use of available area
- Wide range of product families
- Reduce cost by combining functionalities
- Reduce Balance of System (BoS) costs
- ***PV is a functionality!!!***

Price Development for PV Rooftop Systems in Germany (10kWp - 100kWp)

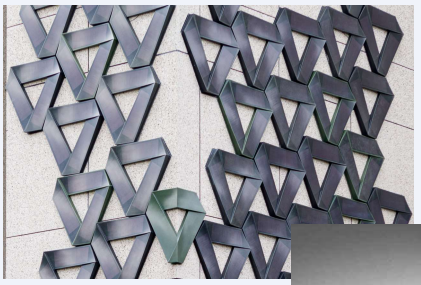
Fraunhofer ISE



Data: BSW-Solar. Graph: PSE Projects GmbH 2024. Date of data: 11/2023

Concept

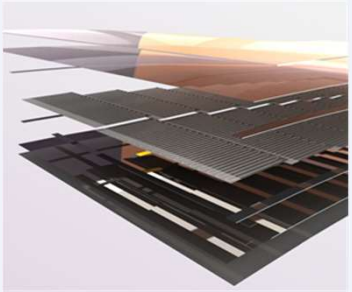
- Make a PV semi-fabricate
  - Bespoke
  - Mass manufacturing methods
- And use it for
  - Building integrated PV
  - Vehicle integrated PV
  - Infrastructure integrated PV



Integration of PV

- Combination of technologies

SMART SEMI-FABRICATES



Solar Laminates

SMART MANUFACTURING

Industry 4.0

SMART INTEGRATION

Solar Products

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(But not in this way)

Source: DAS Energy GmbH – AFAS Experience Center

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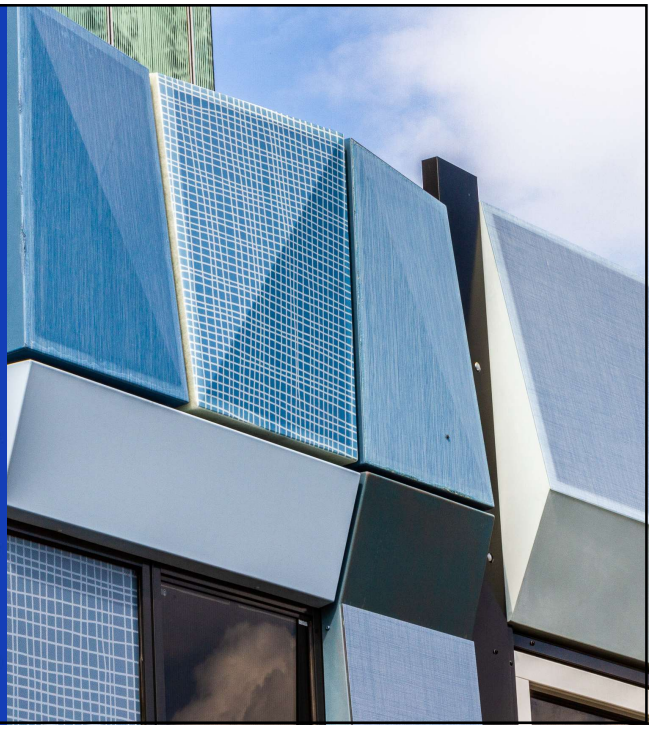
Mass customisation of PV-laminates

A tool for cost effective PV functionality



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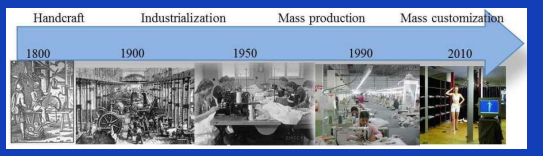
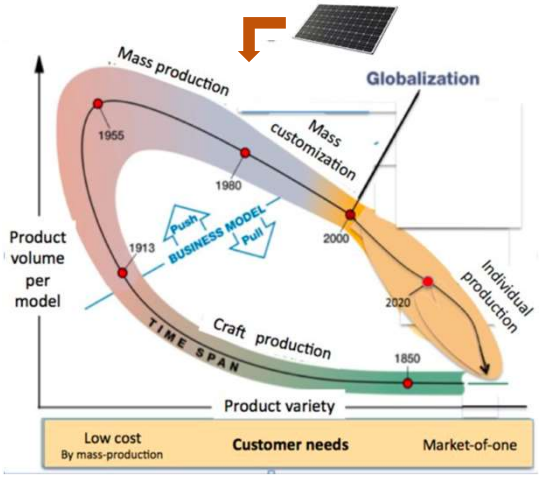
Historic transformation of manufacturing

- Definition (Piller, 2004)
- … “a strategy that combines customized products and services in compliance with the efficiency of mass production”
- … “a perfect bridge for connecting cost pressures and customer-specific requirements”



Development of production condition.



Source: Yoram Koren “The Local Factory of the Future for Producing Individualized Products.”

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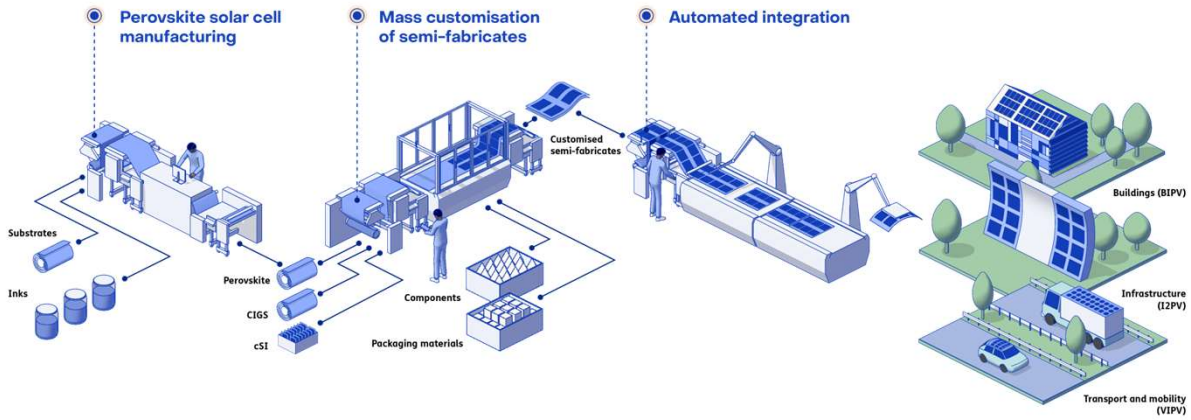
Energy Supply Solar Energy

Mass customisation at various levels



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Productie van zonnepanelen terug naar Europa

Integratie is meer dan massamaatwerk

Esthetiek

Producten moeten volledig estetisch integreerbaar zijn in elk beschikbaar oppervlak (vorm, kleur, ...)

Duurzaamheid

Circulair ontwerp, materialen, recycling, ecologie

Maakbaarheid en integreerbaarheid

Verschijdenheid van producten vraagt om een nieuwe aanpak van fabricage. Massamaatwerk en integratie technologie nodig

Betrouwbaarheid en levensduur

Nieuwe producten en toepassingen hebben eigen eisen aan betrouwbaarheid en levensduur.

Veiligheid

Integratie van zonnelaminaten vraag om onderzoek naar veiligheidaspecten zoals brandveiligheid, elektrische veiligheid, en material eigenschappen

Kosten reductie

Verbeteren van cel en module efficientie, reductive van materiaal kosten, nieuwe slimme fabricage methoden

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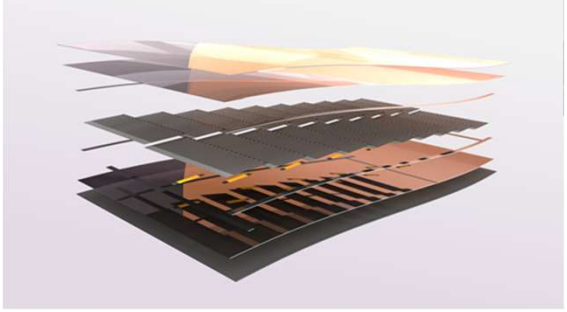
The PV semi-fabricate

- The solar laminate or PV semi-fabricate consists of those elements that are needed to provide durable and reliable PV performance to the product



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Productie van zonnepanelen terug naar Europa

Pilot R&D facility: The Mass-Costumisation line

Foto: Niels van Loon/TNO

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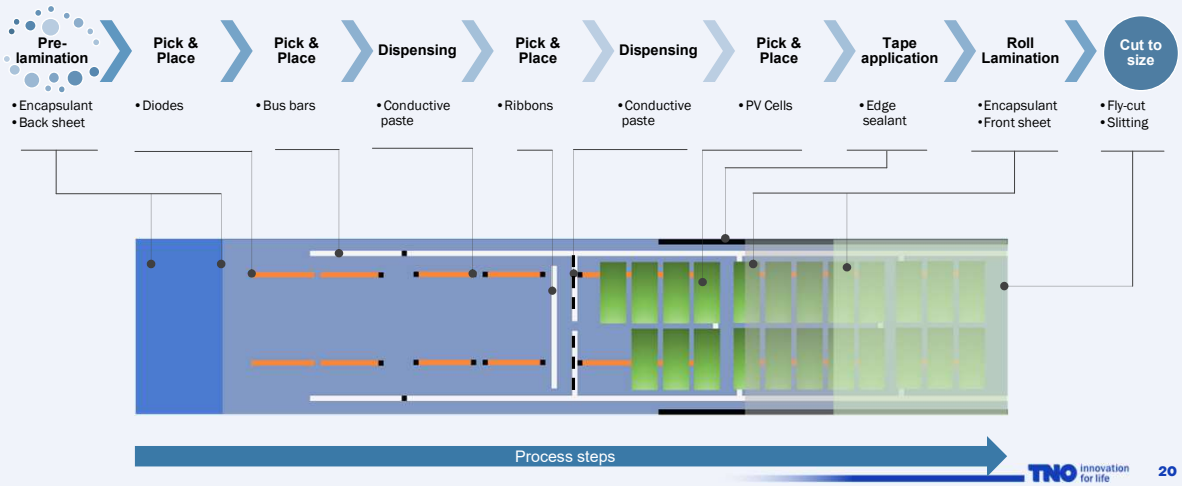
Inline R2R manufacturing

05 August 2024



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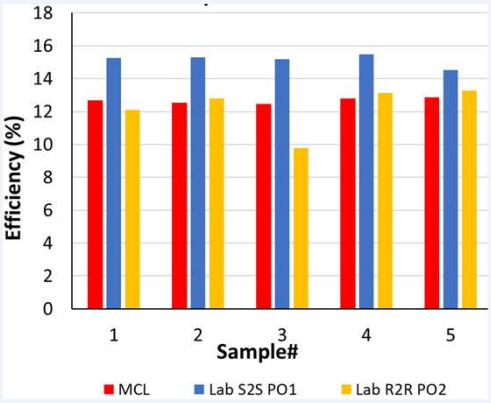
Long flexible PV-Laminates
6M/8M

21

Process Optimisation

- Compare lab with MC-line
  - 5 samples from MC-line compared to 10 samples produced in the lab (R2R & S2S).
  - MCL samples show efficiencies comparable to R2R lab samples before DH
  - S2S consistently performs better, reason being investigated
- Process stability seems acceptable, but needs further investigation



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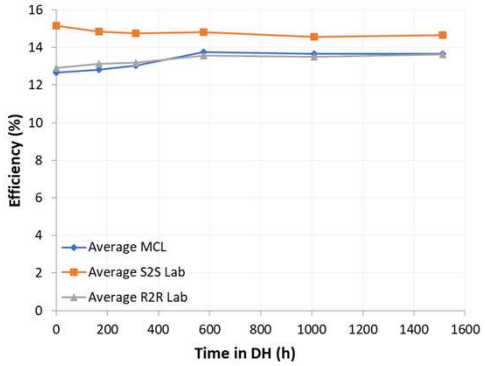
Accelerated lifetime testing



- 5 samples from MC-line compared to 2x5 samples produced in the lab (R2R & S2S).
- 1500 h DH, performance of the R2R Lab and MC-line samples comparable,
- Performance of the S2S samples consistently higher.
- R2R samples also show a gradual **increase** in performance during the first 600 h DH, which is not fully understood.

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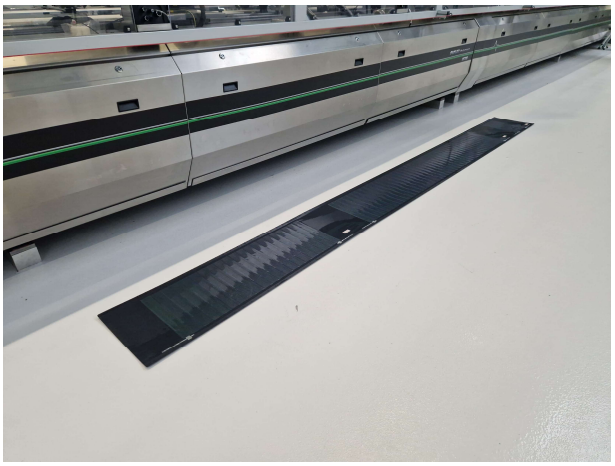
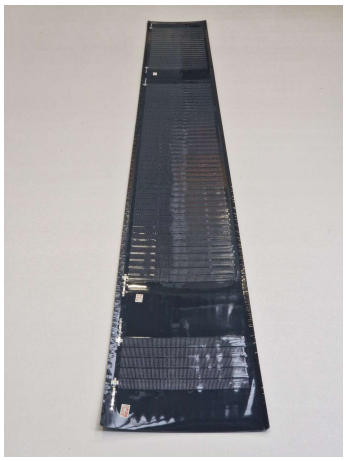
Varying length laminates in one run





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Varying architectures

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Summary

- The challenges are huge: Energy transition, Energy independence, Industrial Indepence
- Integration of PV in the build environment is needed in a crowded country as NL
- This can be done using bespoke PV semi-fabricates
- Mass Customisation allows for the realisation at an acceptable price
- TNO is developing technology for this approach
- Various cell-technologies for various applications: towards Perovskite and (flexible) tandems

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Dank voor uw aandacht

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Mass customisation line

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