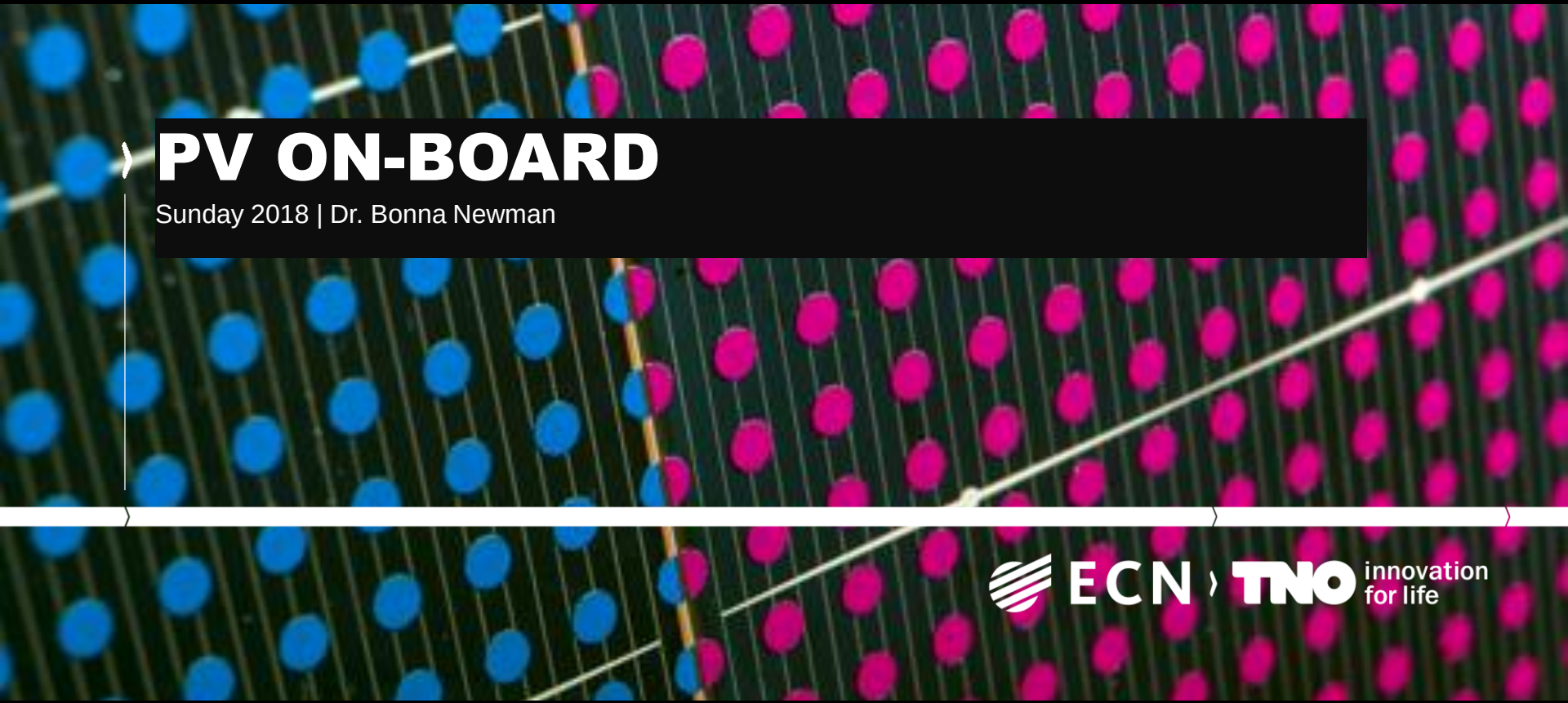


PV ON-BOARD

Sunday 2018 | Dr. Bonna Newman

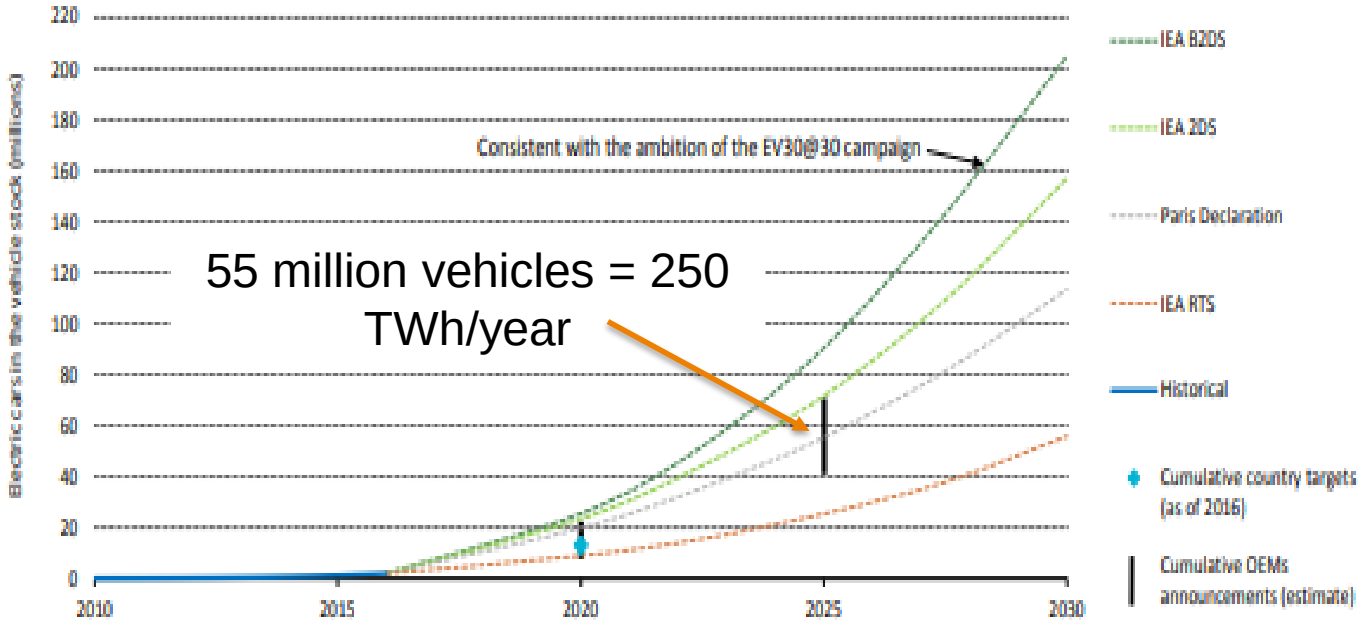
ECN | TNO innovation for life

ACKNOWLEDGEMENTS

Anna Carr
Lars Okel
Victor Rosca
Nico Dekker
Maurice Goris
Peter Blokker

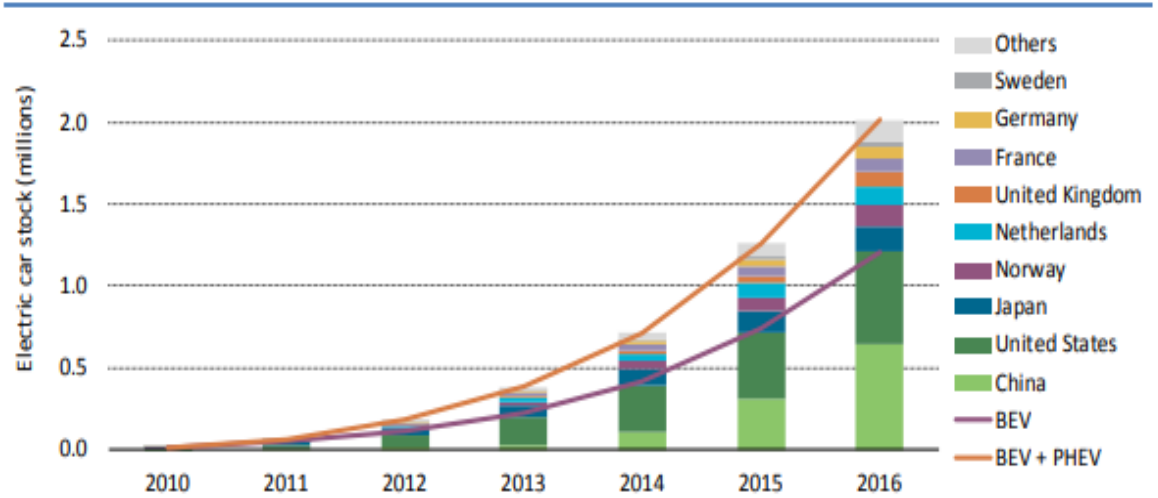
Peter Toonssen
Karel Spee

GROWTH OF EVS



Global EV Outlook 2017 - IEA

ELECTRIC TRANSPORTATION



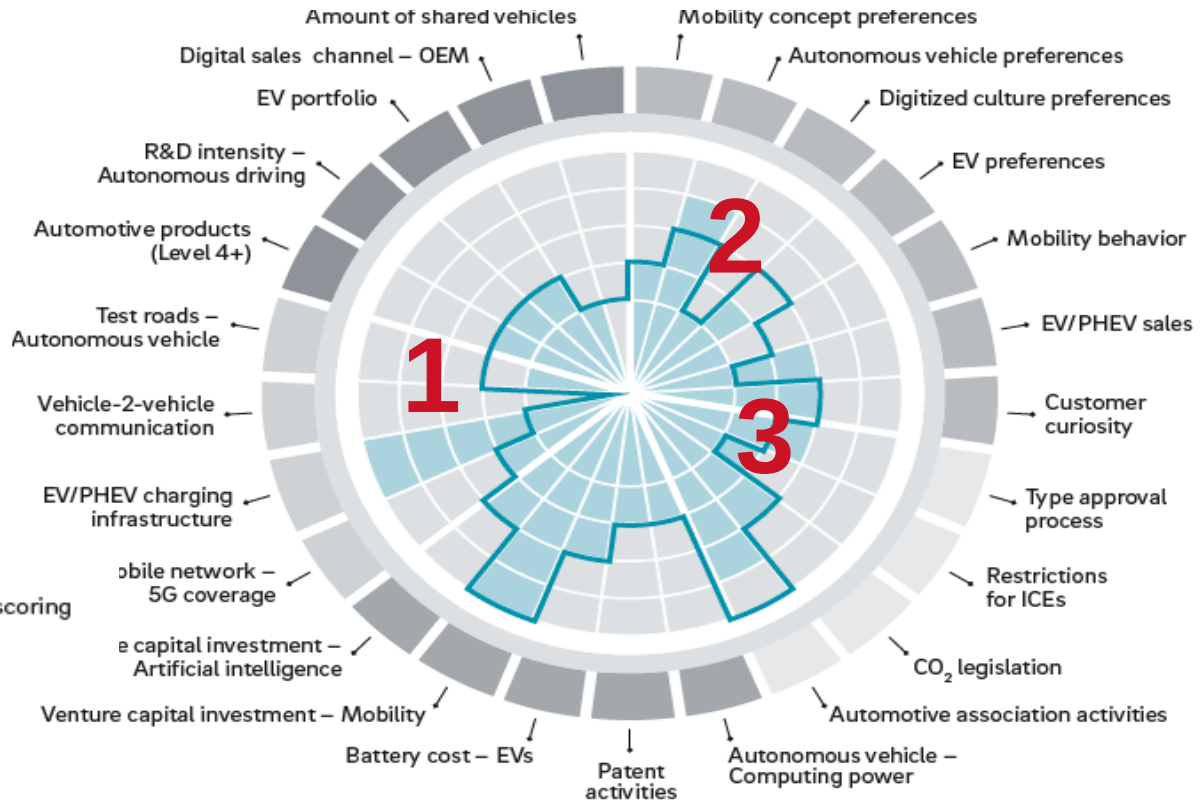
Netherlands – EVs are 6.4% of national market share (2017)

Global EV Outlook 2017 - IEA

NETHERLANDS: #1 COUNTRY FOR EVS

1. Infrastructure
2. Customer Interest
3. Regulations

Policy goal of zero emission vehicles in 2030.

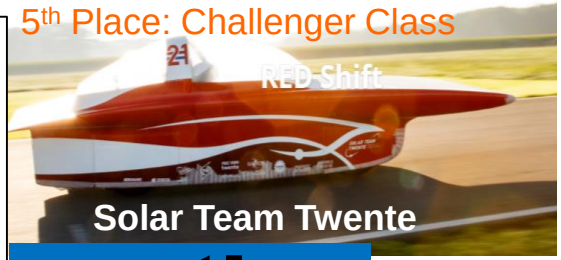


NETHERLANDS CHAMPIONS 2017!

1st Place: Cruiser Class

1st Place: Challenger Class

5th Place: Challenger Class



2nd

1st

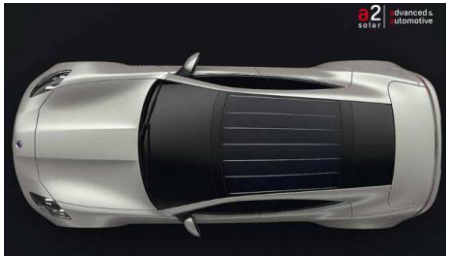
5th

COMMERCIALLY AVAILABLE SOLAR ASSISTED CARS

Toyota Prius PHEV
180 W

Audi e-tron Quattro
400 W

VW Tiguan GTE
110 W



Karma Revero

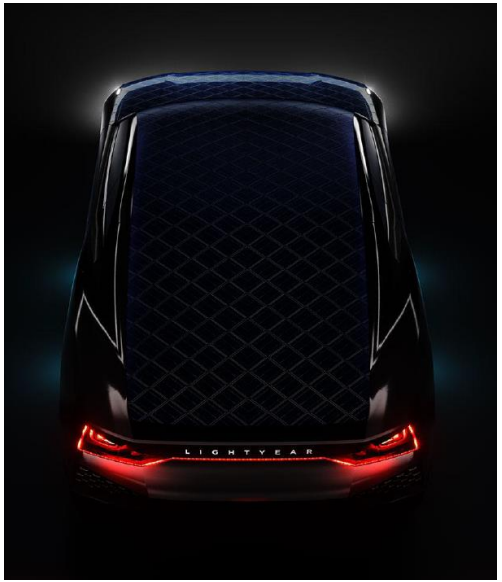
- 200 W solar roof
- 2000 km/yr

LIGHTYEAR

SOLAR POWERED CARS

Sion from Sono Motors

- ~1200 Wp on car
- Sunpower IBC cells
- €19,000

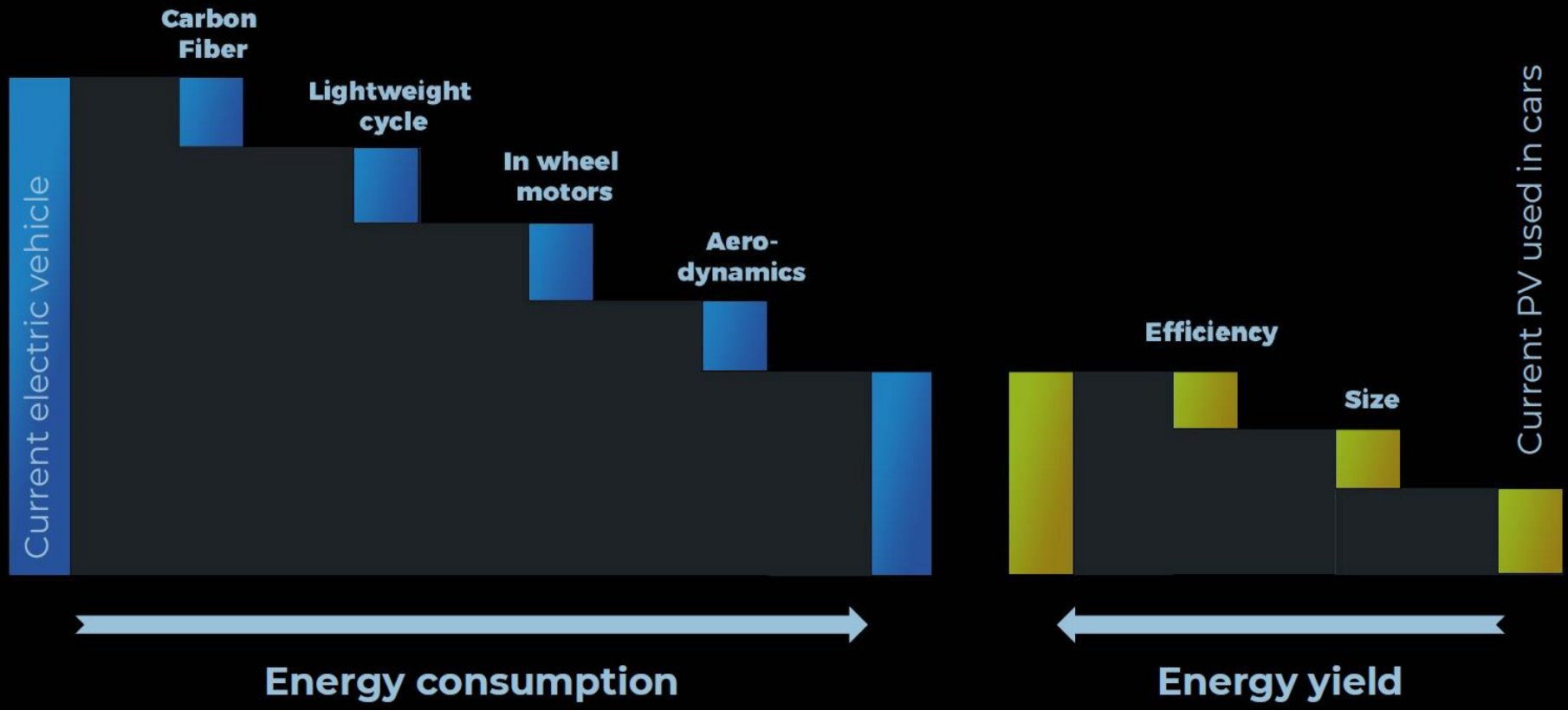


Lightyear One from Lightyear

- > 1000 Wp-effective on car
- IBC cells
- €119,000

So why hasn't it been done before?

LIGHTYEAR

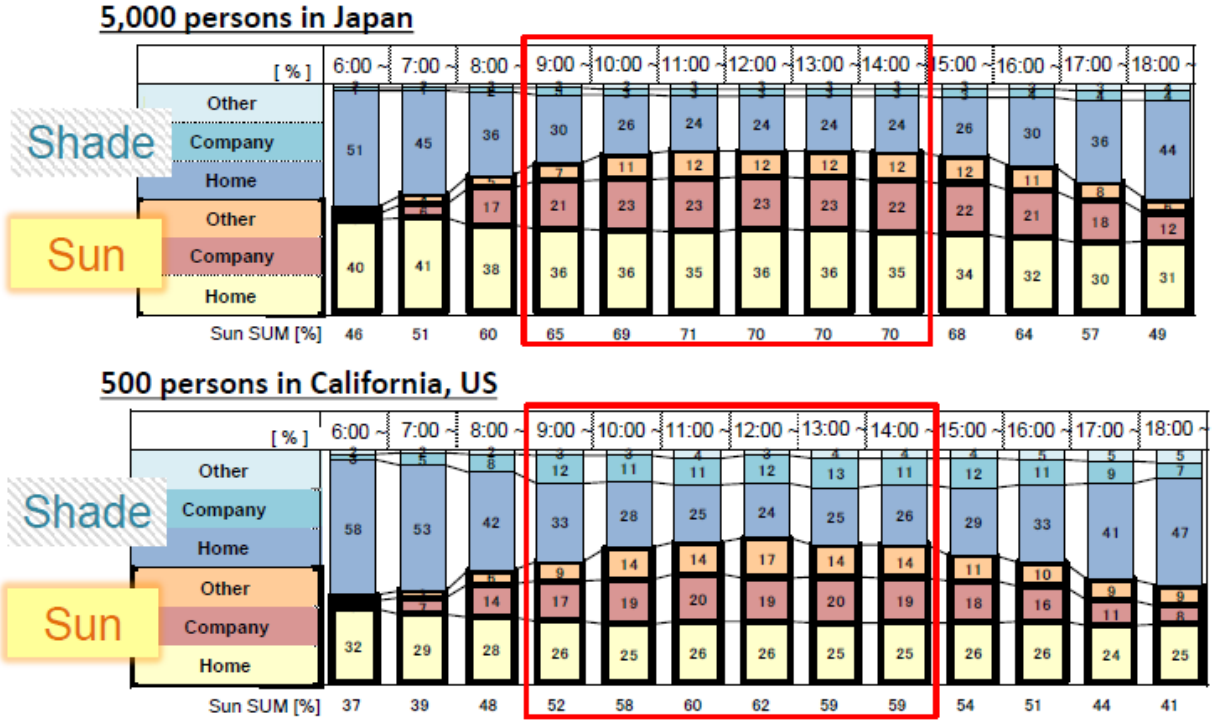


LIGHTYEAR

Hawai	20.000 km
Los Angeles	19.000 km
Madrid	17.000 km
New York	14.000 km
Amsterdam	10.000 km

UNDERSTANDING THE BUSINESS CASE

- Styles of driving
  - Commuter
  - Family car
  - Car sharing
  - Taxi
  - Delivery
  - Long haul



Study results from Akinori Sato, Toyota R&D

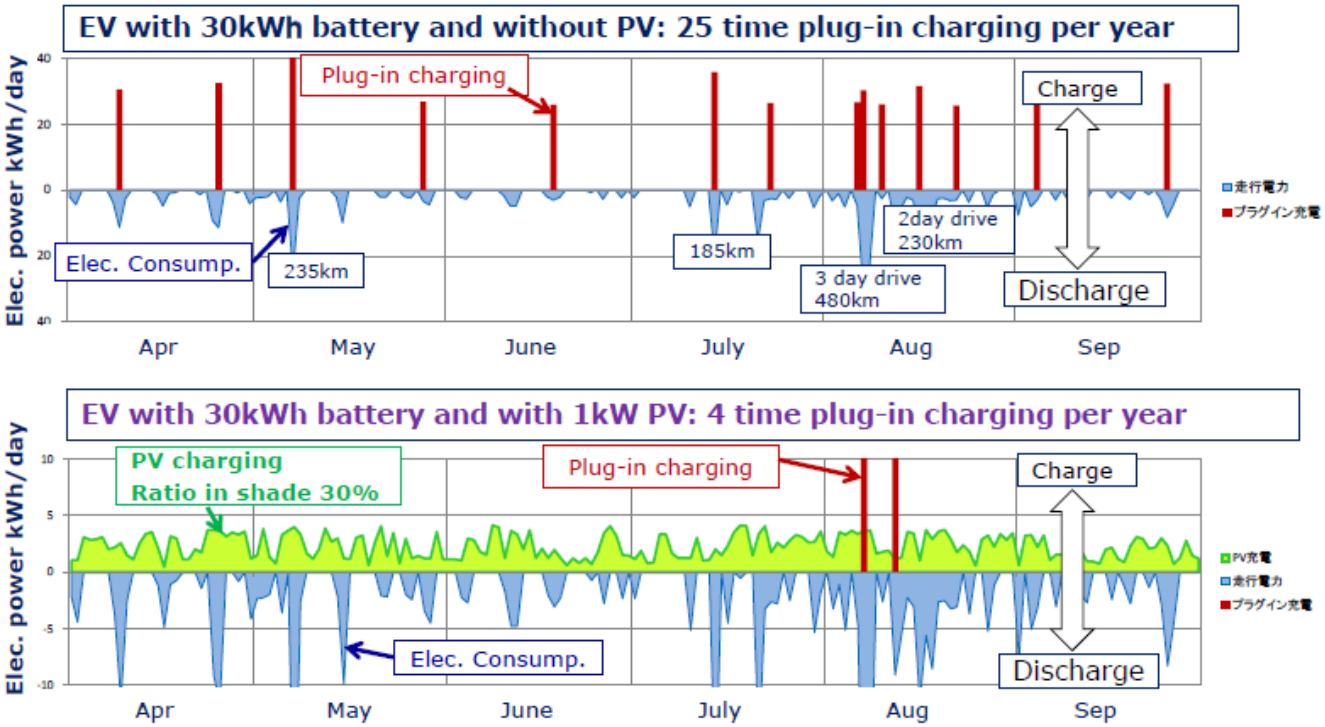
WHY SOLAR-POWERED CARS?

25 plug-ins per year

Grid demand
CO_2 emissions

4 plug-ins per year

* Analysis based on actual driving (6310 km/yr) and irradiance data in Japan for 30 kWh Nissan Leaf



Toshio Hirota, Environmental Research Institute, Waseda University, Japan

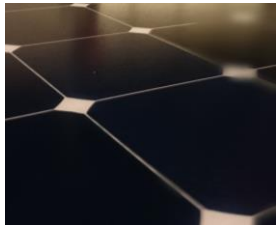
TRANSPORT MARKETS CHARACTERISTICS

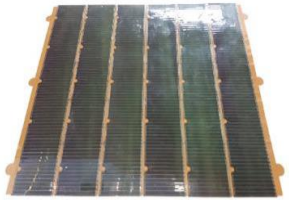
Automotive		
Passenger cars	– Most innovative, largest R&D budgets	2 – 6 m^2
Trucks, vans	– large impact, good delivery	30 - 45 m^2
Off-Highway	– remote operation extension, specific niches	
Specials vehicles	– city service vehicles, etc.	
Buses		
Buses	– Urban public transport transition to Zero Emission	25 - 40 m^2
Coaches	– Private tours, eco-tourism	< 40 m^2
Rail		
Train	– Energy footprint reduction	150 - 400 m^2
Tram / Light rail	– Energy footprint reduction	50 - 100 m^2
Ships		
Inland shipping	– support transition to low carbon (hybrid) propulsion	250 - 3000 m^2
Yachting	– added luxury and autonomy, silent hotel function	10 - 100^+ m^2
Marine	– support transition to low carbon (hybrid) propulsion	500 - 10.000 m

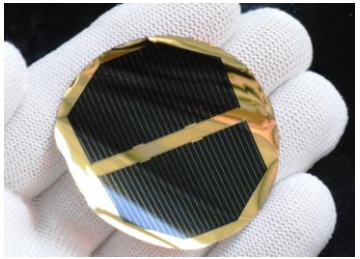
TECHNICAL CHALLENGES FOR PV ON CARS

- Maximum performance (Max. sun-facing area 5 m^2)
  - 20+% efficiency – laminated (flat?)
  - Curved surface > 85% utility
  - Good shade performance (<30% shading losses)
- Lightweight for vehicle efficiency
- Aerodynamics and Aesthetics
  - Needs to flexibly follow car roof
    - – reduced drag (30% less than current best in class vehicles)
  - Materials, coatings, and layout
- Reliability
  - 15 years
  - High wind and speed damage

WHICH TECHNOLOGY?



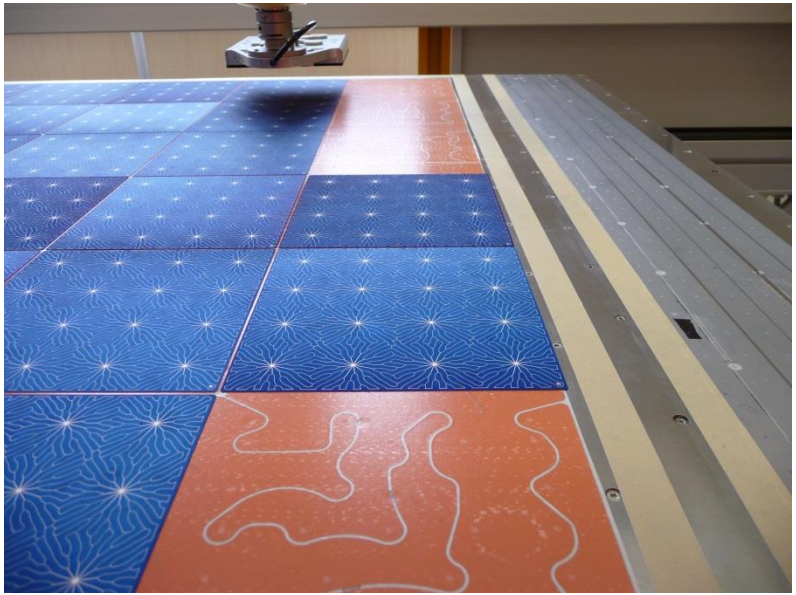




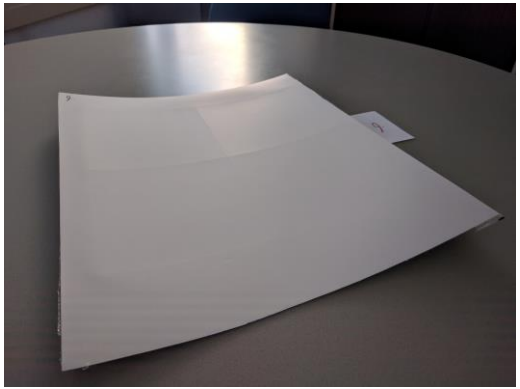
	c-Si	Thin-Film (CIGS)	MJ - III-Vs
Efficiency	24%	17%	29%
Power Density/Weight	+?	+	++
Flexibility	?	++	++
Cost	++	+	--

CONDUCTIVE BACK CONTACT FOIL

- Designed for highest efficiency c-Si cells
- Flexible circuit and cell placement
- Variable sizes
- Easy lamination process
- Proven high-volume manufacturing (Eurotron)

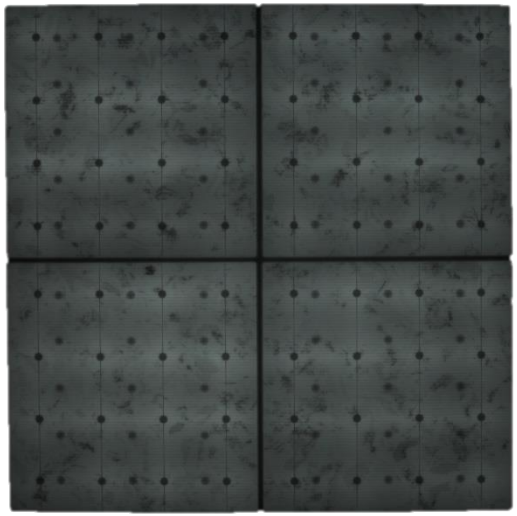


TEST STRUCTURES

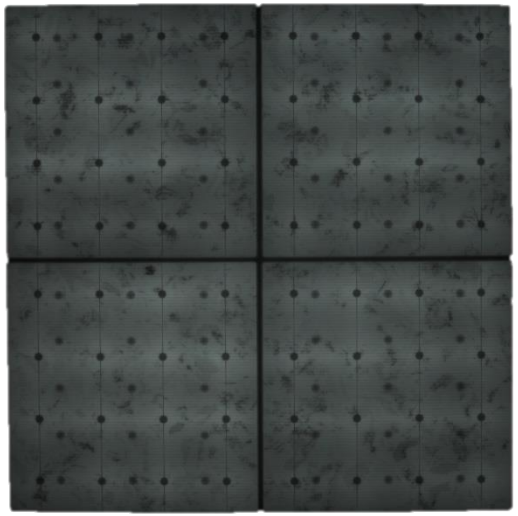


cross section

FLEXIBILITY AND AERODYNAMICS

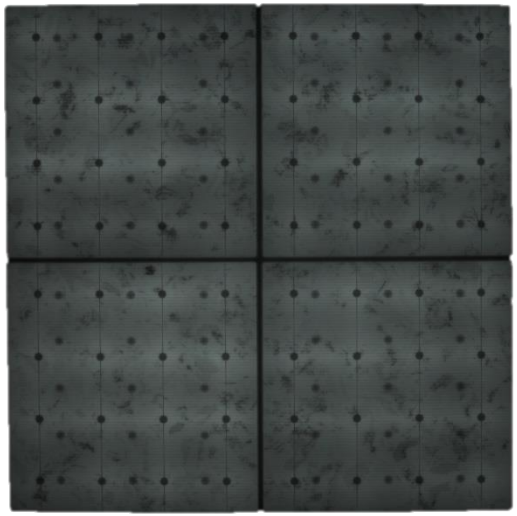


Flat

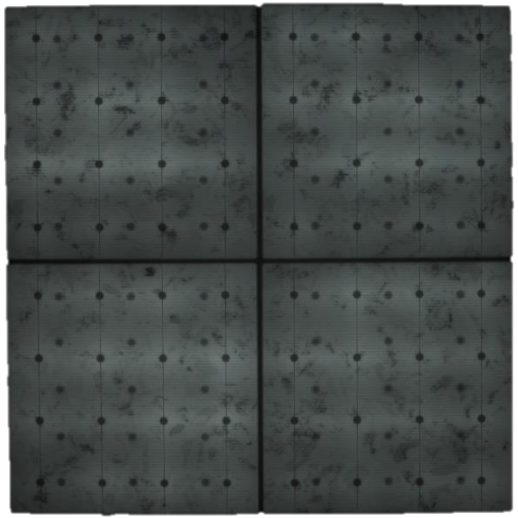


$R_{curv.}$ = 178 cm

FLEXIBILITY AND AERODYNAMICS

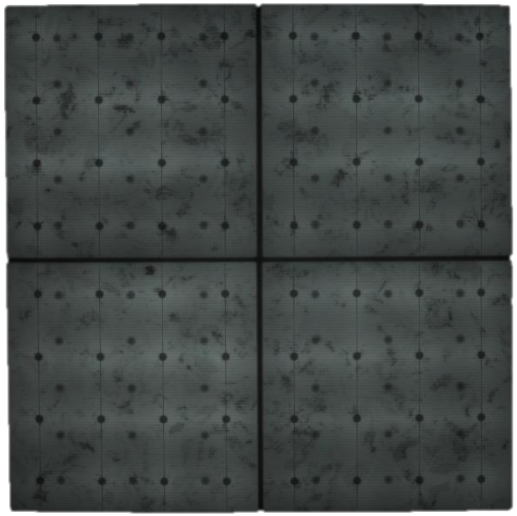


Flat

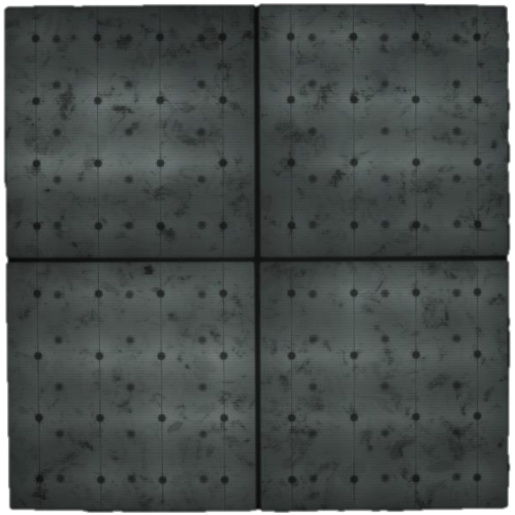


$R_{curv.}$ = 30 cm

FLEXIBILITY AND AERODYNAMICS



Flat

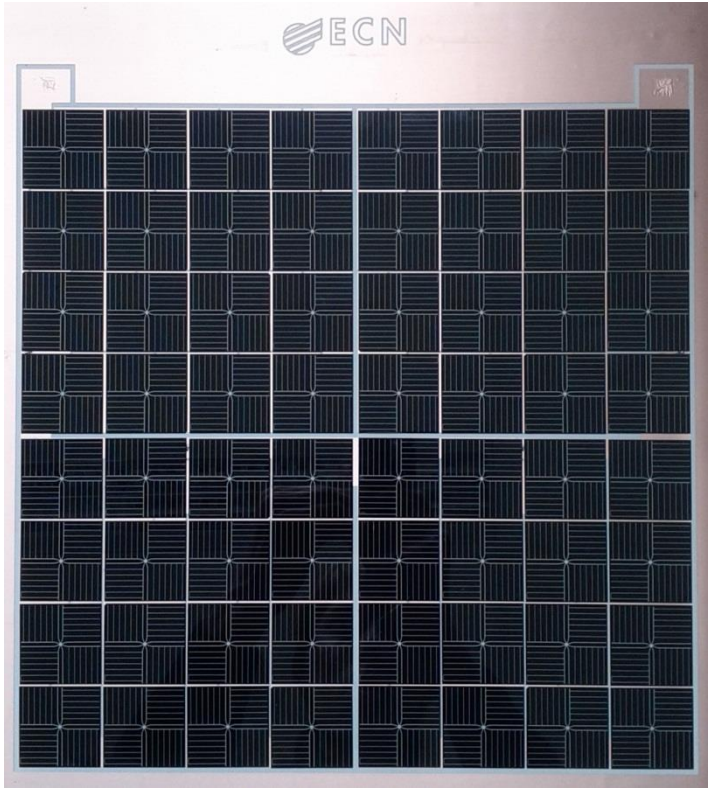


$R_{curv.}$ = 12.5 cm

Δeff = -0.9%

MAXIMUM YIELD

- Small cells
- Conductive foil used to create specific circuitry
  - Tunable voltage and current
  - Integration of other components in foil
- Excellent partial shade performance

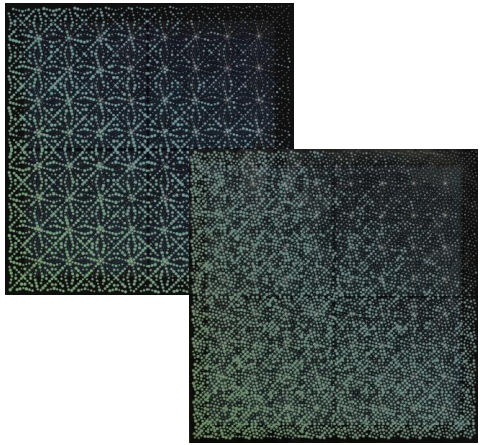


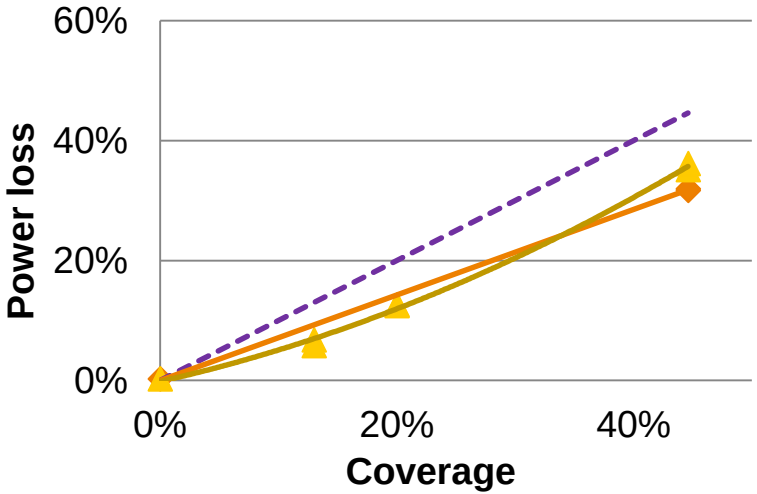
LIGHTWEIGHT, FLEXIBLE MODULE

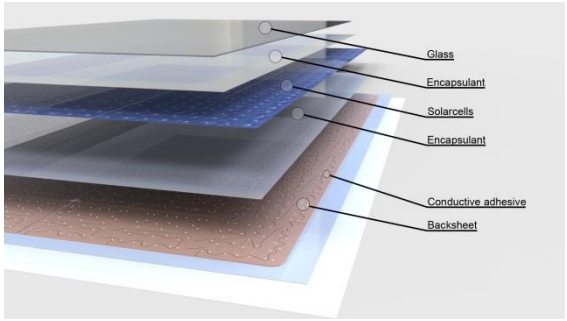
- Glass free – semi-flexible
- Small cell with built in dynamic performance
- Matte finish for aesthetics

	c-Si
Efficiency	24%
Power Density/Weight	++
Flexibility	++
Cost	++

AESTHETICS







http://www.dsd-pv.nl/

SOLAR ELECTRIC VEHICLES

- c-Si can be made flexible and lightweight
- Components are now available and cost effective
- PV efficiency high enough to significantly contribute to power demands of electric vehicles
- Technical developments are easily applicable to BIPV and other mobile applications

- Many questions still need answers
  - Real-time performance and lab testing?
  - Reliability and repairability?
  - Safety?
  - Manufacturability and costs?

IEA PVPS TASK 17: PV IN TRANSPORT

1. Identify expected/possible benefits and requirements
2. Identify barriers and solutions
3. Deployment of PV equipped charging stations
4. Integrating PV-powered vehicles with electrical systems
5. Develop a roadmap
6. Involve international stakeholders

WANT TO GET INVOLVED?

Join Task 17

- We need:
  - **Research Institutes** to collect and analyze local data
  - **Automotive Industry** to define targets, markets, and direct technology needs
  - **EV supply chain companies** to define vehicle demands
  - **EV charging/infrastructure companies** to define charging modes
  - **Governments or Other** to define driving models and government needs

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THANK YOU FOR YOUR ATTENTION
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