Trends in PV for transport, a summary of IEA PVPS Task 17

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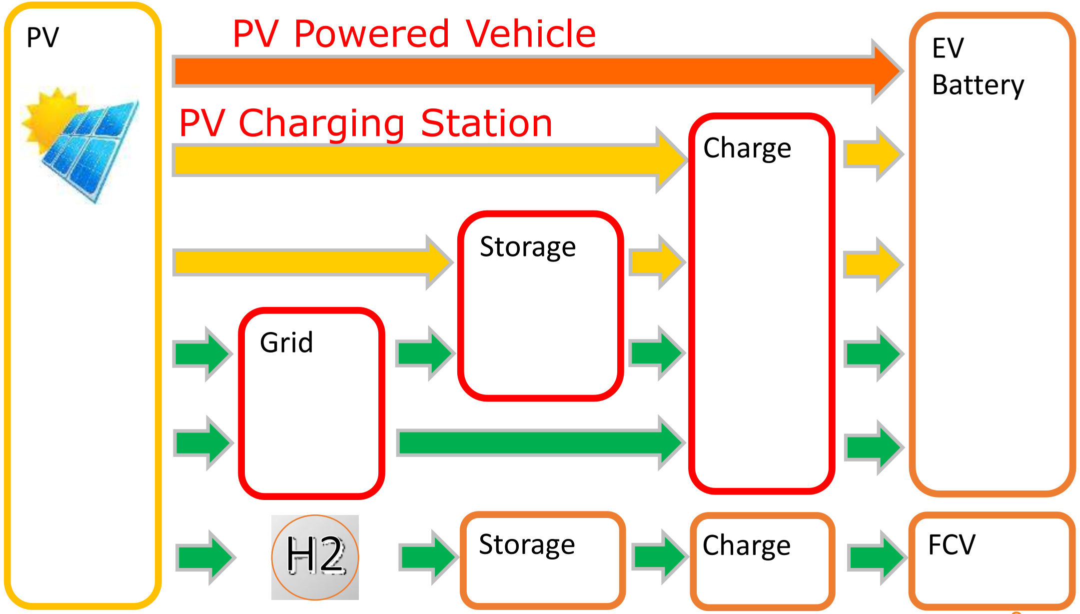
IEA PVPS Task 17 ‘PV and Transport’

Approaches for decarbonizing transport

- Renewable energy based – ‘Fuel’
  - Bio-fuel
  - Power to Fuel, such as hydrogen and methane
- Renewable electricity
  - Infrastructure
    : such as PV charging station
  - Direct integration
    : such as PV-powered vehicles

(https://www.nedo.go.jp/news/press/AA5_101150.html)



Motivation

- Mobility should be released from
  - Fossil fuels
  - Energy charging (any fuels, electricity)
- Mobility should be a key part for creating sustainable energy system

Goal

Deployment of PV usage in the transport

- ➢contribution to reducing CO_2 emissions
- ➢enhancement of PV market expansions

Objectives

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1. Clarify expected/possible benefits and requirements for PV-powered vehicles
2. Identify barriers and solutions to satisfy the requirements
3. Propose directions for deployment of PV equipped charging stations
4. Estimate the potential contribution of PV in transport
5. To realize above in the market, contribute to accelerating communication and activities going ahead within stakeholders such as PV industry and transport industry

Subtask Structure of Task 17

Subtask 1: PV-Powered Vehicles

**Clarify the benefits and requirements for PV-powered vehicles and components*

**Identify barriers and solutions to satisfy the requirements*

Subtask 2: PV charging systems and PV power infrastructures

**Propose directions for deployment of PV equipped charging stations and PV power infrastructures*

Subtask 3: Potential contribution of PV in transport

**Estimate the potential contribution of PV in transport and propose milestones*

Subtask 4: Dissemination

**Accelerating communication and activities going ahead within stakeholders such as PV industry and transport industry*

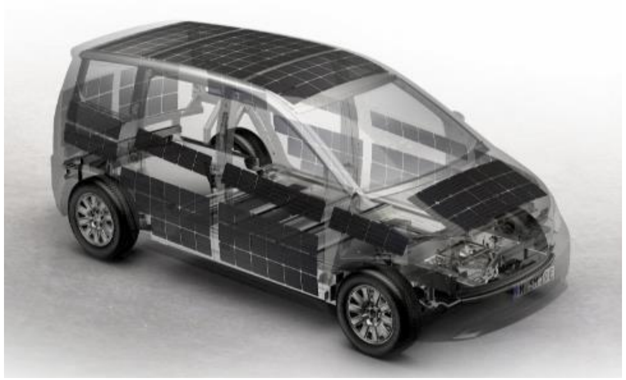
PV-powered vehicles: Prototype and research stage

Stage	Proto type	Proto type	Proto type	Demo. Car	Demo. Car
Manufacture or Development	Sono motors	Lightyear	Hanergy	NEDO, Sharp, Toyota	NEDO, Sharp with Nissan
Model	Sion	Lightyear One	Hanergy Solar	Toyota Prius	Nissan e-NV200
Production	Plan: 2022	Plan: 2023	-	-	-
Type	BEV	BEV	BEV	PHV	BEV
Battery capacity	35 kWh	60 kWh		8.8 kWh	40 kWh
PV surface	7.5 m2	4 m2	3.5 to 7.5 m2		
PV capacity		1,250 W		860W	1,150 W
PV type	Si	SunPower Maxeon	2 junction Ⅲ-Ⅴ	3 junction Ⅲ-Ⅴ	3junction Ⅲ-Ⅴ
Motor	120 kW	80 kW		110 kW	80 kW
Range	255 km-WLTCstd	708 km with PV			300 km-JC08
Solar Range	Up to 34 km/day	32 km/day ave.		56.3 km/day max	
Year info.	2020	2019	2019	2019	2020

Source: https://sonomotors.com/en/sion/ and other net info.

Sono motors "Sion"

- Sono motors developed an EVs for daily use with PV, the Sion.
- Driving range is 250 km and additional range by PV is 34 km a day.
- First generation car prototype to the public in 2017
- More than 12,400 people have reserved and partially paid for the vehicle.
- The first model is planned to enter production in 2022.



Source: https://sonomotors.com/en/sion/

Lightyear One EV

- 20 miles of average range per day with 1.25 kW SunPower Maxeon cells
- 1,000 PV cells, about 1 in. X 4 in. and a few dozen micro-inverters
- Four motors, ultra-lightweight and low Cd. of less than 0.2.
- Single charge driving range with 60 kWh battery and PV: 708 km
- Start road tests in 2019 and plan to introduce to the market in 2023

Source: https://www.sae.org/news/2020/03/lightyear-one-solar-ev

Recent Topics in Japan

- **Demonstration cars developed by NEDO project**
  - 1st demo car in 2019 : NEDO, Sharp Corporation and Toyota Motor Corporation
  - 2nd demo car in 2020 : NEDO and Sharp Corporation with Nissan Motor Corporation

	1st demo car in 2019	2nd demo car in 2020
Car	TOYOTA Prius-PHV	Nissan e-NV200
Type	Plug-in Hybrid Electric Vehicle	Battery Electric Vehicle
driven by	Electric motor and engine	Electric motor
Battery capacity	8.8 kWh	40 kWh
PV capacity	860 W with triple-junction III-V comp.	1,150 W with triple-junction III-V comp.
	 (https://www.nedo.go.jp/english/news/AA5en_100408.html)	 (https://www.nedo.go.jp/news/press/AA5_101326.html)

PVPS

Vehicle solar irradiance measurement

TNO, Netherlands	ISFH, Germany	Univ. of Miyazaki, Japan	Bern University of Applied Sciences, Switzerland	UNSW, Australia
Four horizontal pyrometers and PV module on roof rack	Sub µs irradiance measurements	Five direction pyrometers on roof rack	Five reference cells on two types of vehicles	Low-cost, autonomous irradiance sensor installed on a large number of vehicles
				
Highly fidelity irradiance measurements on horizontal plane. Partial and dynamic shading quantified	Highly fidelity irradiance measurements with high temporal accuracy	Highly fidelity irradiance measurements in all directions.	Highly fidelity irradiance measurements in all directions.	Crowdsourced irradiance and driving data under 'real-world' conditions, including parking behaviour

Energy flow model

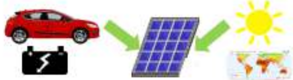
Location

Location	Energy used in car [kWh / year]	PV gen. [kWh / year]	PV util. [%]	CMs No PV	CMs with PV	Economic benefit [€ / year]	Avoided CO_2 [kg/year]
De Bilt	1477	756	98	58	34	223	260
De Kooy	1478	827	96	58	32	237	276
Lelystad	1479	791	98	59	33	231	270
Maastricht	1486	786	99	59	33	234	273
Madrid	1518	1209	98	62	20	354	410
Stockholm	1537	733	66	60	37	218	254

Plug-in grid charging cost € 0.30 / kWh

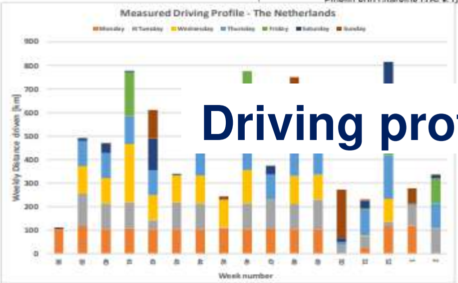
Avoided CO_2 – PV utilised x emission factor
CO_2 emission factor – IEA World Energy Outlook 2015, (NEDO report) 0.35kg-CO_2 / kWh

ENERGY FLOW MODEL
STATUS AND DEVELOPMENT

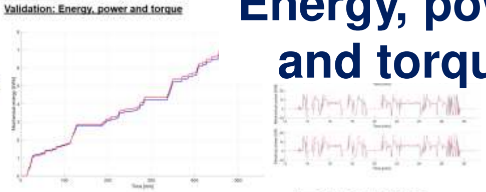


- Outputs
  - Charging moments, economic benefits, avoided CO_2
- Variables / inputs
  - Driving profile, charging strategy, location
  - Vehicle specifications, PV specifications
- Measured driving profile -
  - To be extrapolated to full year
  - Applied to different locations
- Measured driving speed – GPS data
  - Applying to detailed EV model to determine realistic energy use
  - To be compared with basic EV model in Energy Flow model and included as option

Driving profile



Energy, power and torque



PVPS

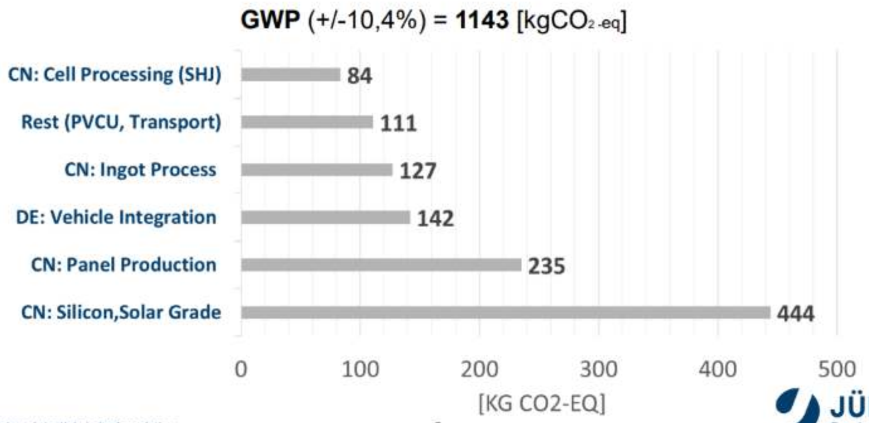
Reference: A.J. Carr, E. van den Tillaart, A.R. Burgers, T. Köhler, B.K. Newman, *VIPV – Evaluation of the Energy Yield Potential through Monitoring and Modelling*, 37thEU PVSEC, Online, Sept. 2020.

Light utility vehicles: Life cycle CO_2 emission

Environmental Impacts of PV on Electric Light Utility Vehicles by Germany team

- Manufacturing process CO_2 emission: 1143 kgCO2-eq. (930 Wp)
- Options for CO_2 reduction: Green production, 2nd use of VIPV, Recycling

RESULTS: MANUFACTURING



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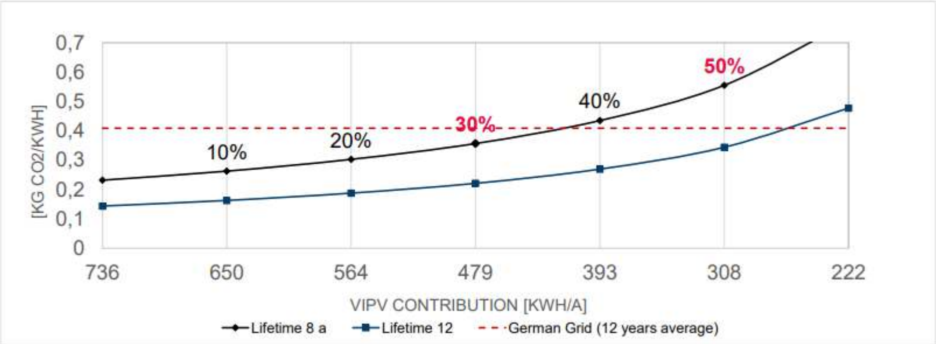
RESULTS EMISSION FACTOR – 12 YEARS OPERATION



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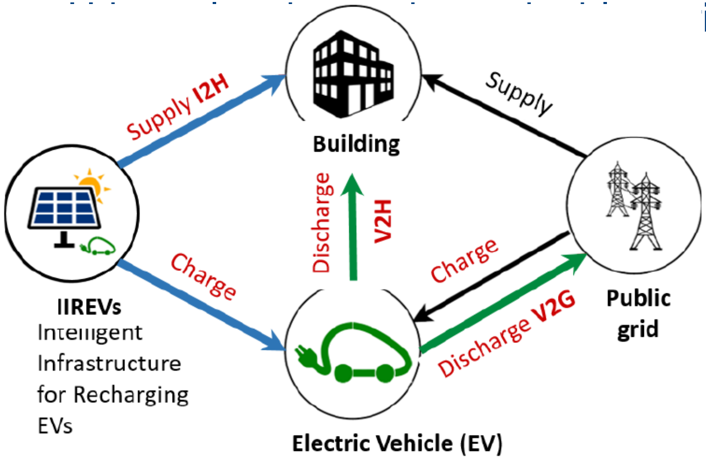
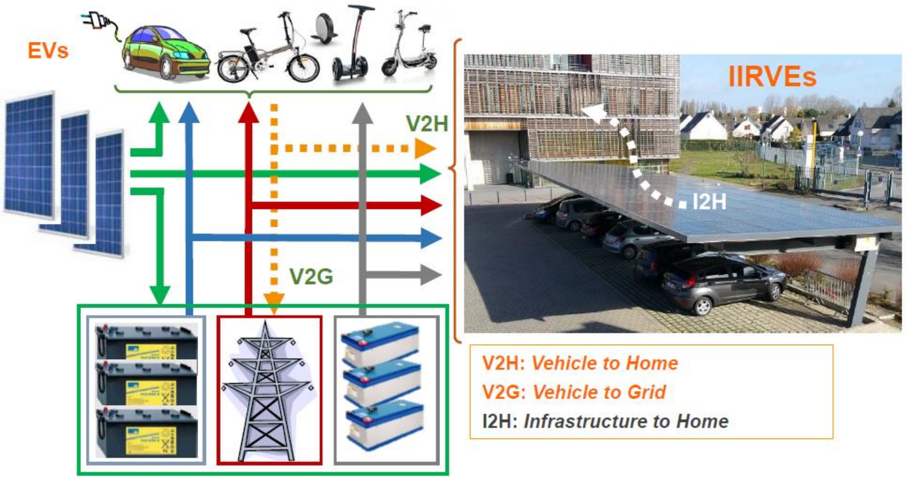
PVPS

Reference: Dr. Kaining Ding / Olga Kanz, Environmental Impacts of Integrating Photovoltaic Modules on Electric Light Utility Vehicles, Forschungszentrum Jülich, IEA PVPS Task 17 meeting, 18 May 2020

Expanded concept on PV-powered charging stations

- **Intelligent infrastructure recharging electric vehicles (IIREVs)**
  - Renewable energy micro-grids
  - Transport and electro-mobility





(Ref. Sechilariu, Manuela et al., Electromobility framework study: infrastructure and urban planning for EV charging station empowered by PV-based microgrid, *IET Electrical Systems in Transportation* (2019), 9 (4):176)

List of TASK 17 Participants

Country	Organization
Australia	ITP Renewables, University of New South Wales
Austria	DAS Energy
China	Institute of Electrical Engineering Chinese Academy of Sciences
France	Université de Technologie de Compiègne, TECSOL SA, ADEME, SAP, CEA, Enedis, Polymate, EATON
Germany	Institut fur Solarenergieforschung GmbH Forschungszentrum Jülich GmbH
Japan	Waseda University, MHRI, University of Miyazaki
Morocco	Green Energy Park
Netherlands	TNO, University of Twente, IM Efficiency
Spain	TECNALIA
Switzerland	Bern University of Applied Science

Recent research at Waseda Univ. Japan

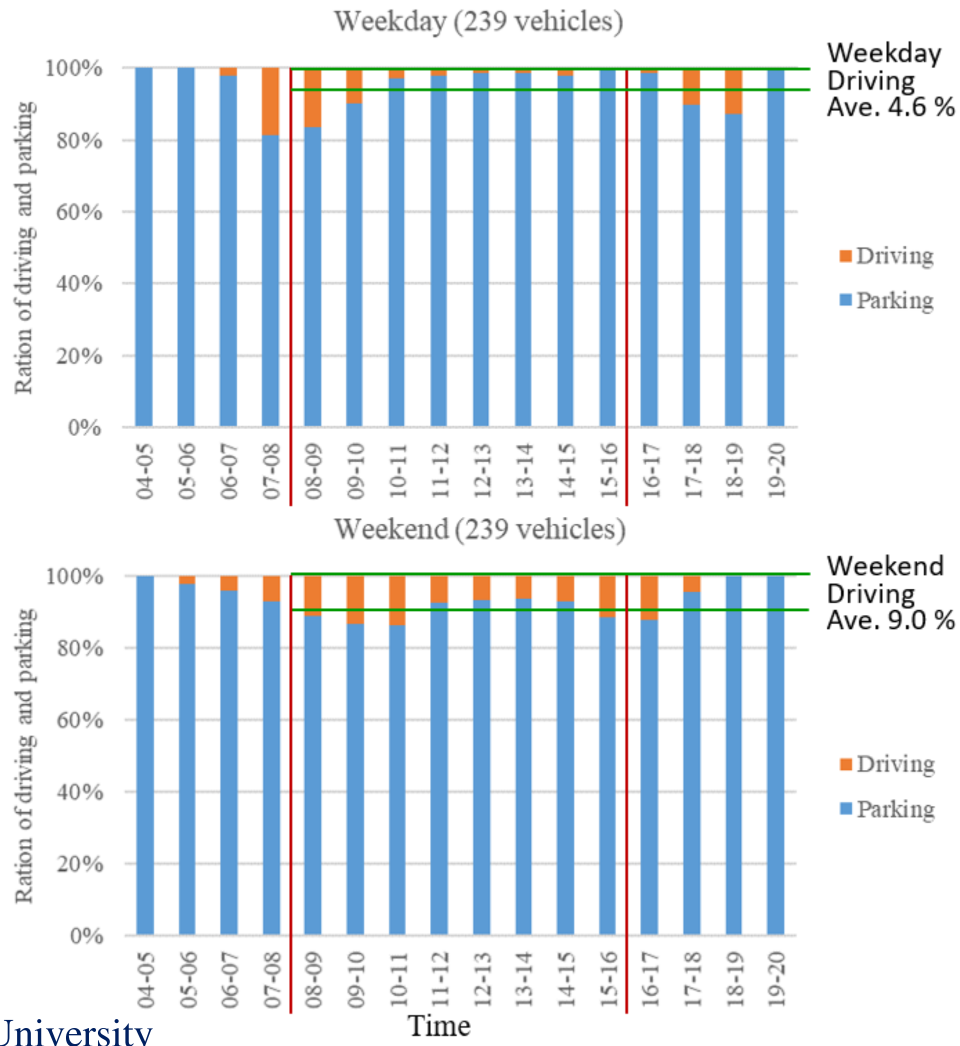
- Customer survey for PV-powered vehicle
- Vehicle test for irradiation measurement
- Simulation model analysis for energy balance

Customer survey

Daytime: More than 90% of cars are parking at daylight hours.

Survey: 239 Passenger cars
Driving / Parking condition

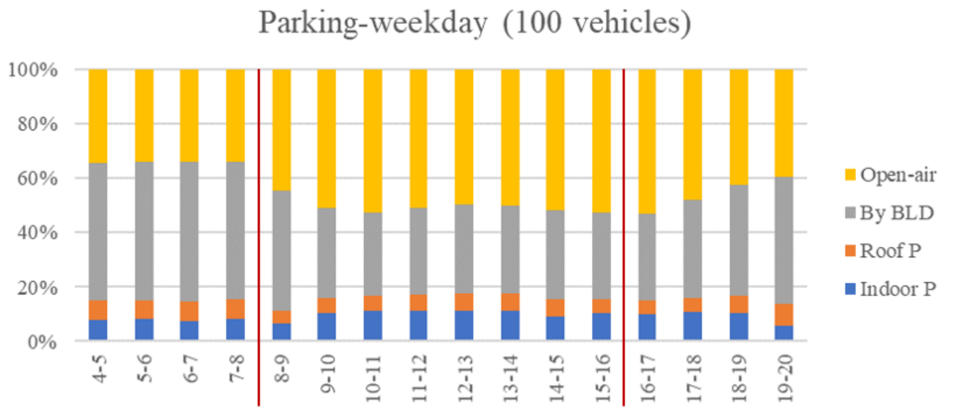
- 8:00-16:00: 90% of daily irradiance
- Weekday: driving vehicles 4.6%
- Weekend: driving vehicles 9%

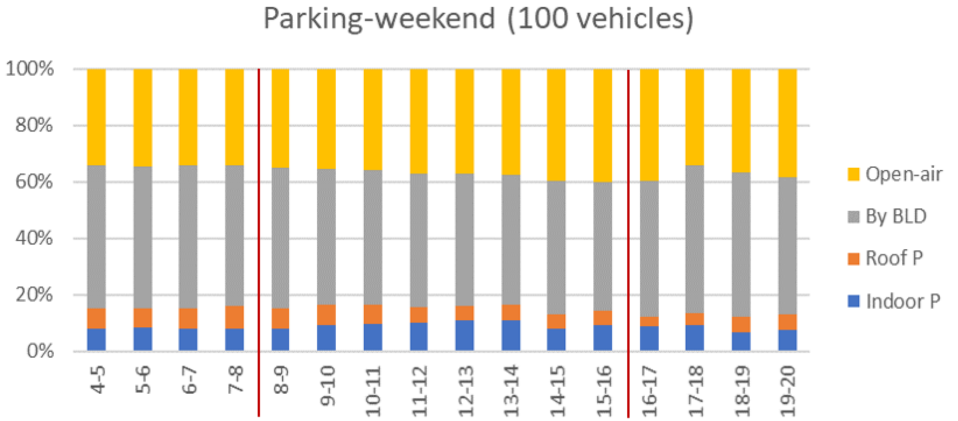


Customer survey

Breakdown of parked vehicles

- Parking condition of 100 vehicles, 70 commuting and 30 non-commuting
  Ratio of parking condition from 8:00 thorough 16:00
- Weekday: Open-air 50%, By the building or house 33%, Roof carport 7%, Indoor 10%
- Weekend: Open-air 42%, By the building or house 45%, Roof carport 7%, Indoor 8%

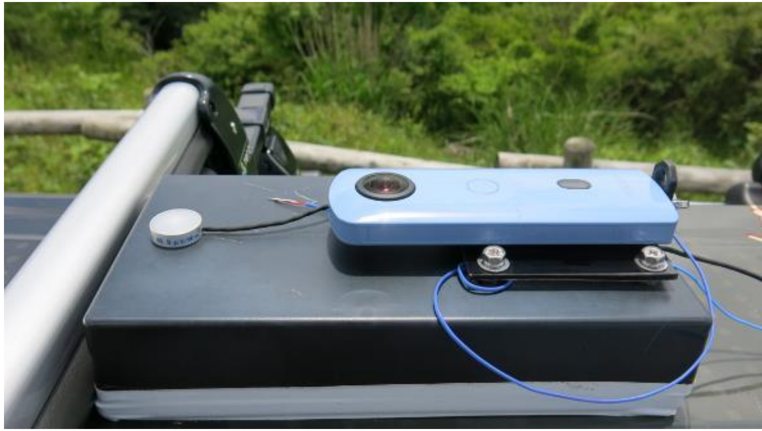




Vehicle test for solar irradiance measurement

Solar irradiance measurement under driving/parking real-world conditions to evaluate the shadow effect by the buildings, trees, signboard etc.

- Vehicle: 2016 Nissan LEAF
  Curb weight 1,460 kg
  Electric consumption
  117 Wh/km (AC, JC08 mode)
- Irradiance sensor: Si type compact sensor
- Temperature sensor: K type
- Camera: Spherical camera, RICOH SC2
- Data logger: GRAPHTEC GL220
  HIOKI Data mini LR5041



Road test for irradiance measurement on the vehicle

Suburbs: Shonan beachside drive

High rise: Tokyo subcenter

V/F: Vehicle/Fixed irradiance ratio by road test analysis

Annual average V/F for driving and parking condition

Driving	HWY	Suburbs	Urban	High-rise
Average shade height	10 deg	15 deg	30 deg	50 deg
V/F	0.96	0.93	0.75	0.46
Parking	Open-air	S of BLD	E,W of BLD	N-of BLD
Ave. shade height	15 deg	30 deg	30 deg	30 deg
Shade height of near BLD		70 deg	70 deg	70 deg
V/F	**0.93**	**0.75**	**0.71**	**0.58**

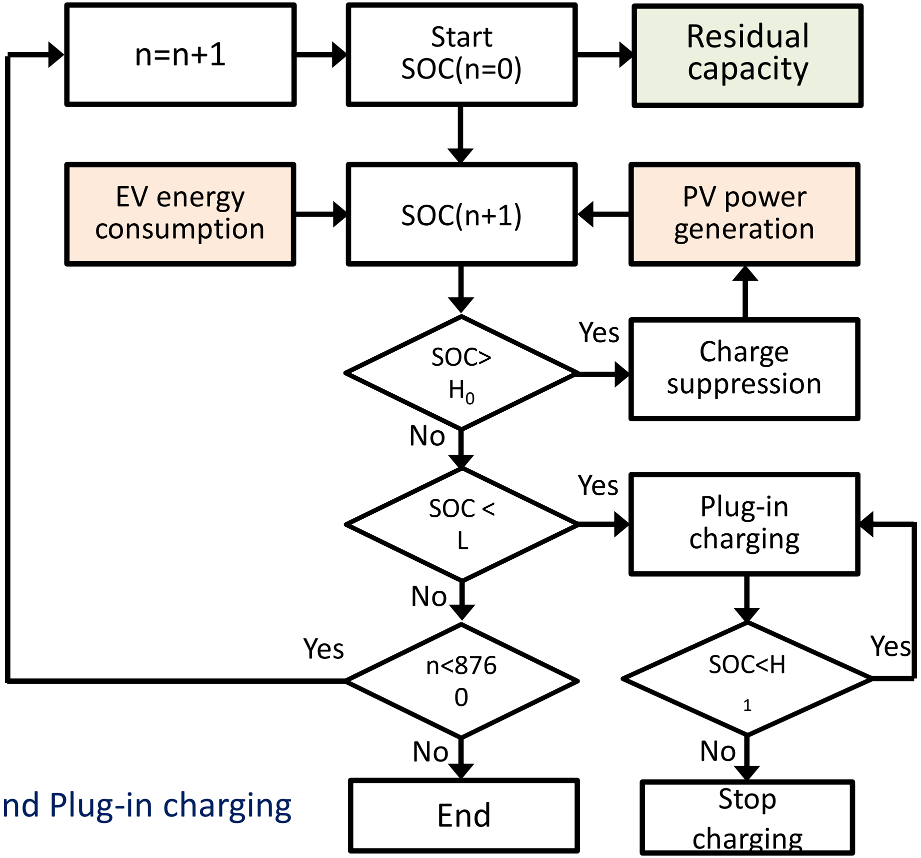
Case study: Energy balance / EV energy cons. and PV generation

Prerequisites of the simulation model

PV	Rated output power	1.0 kW
	Conversion efficiency	33.4 %
	PV panel area	3.0 m^2
PV/Power management system	Temperature factor	91 %
	MPPT efficiency	95 %
	Efficiency of DC conv. Batt.	93 %
Battery	Capacity	30 kWh
	Residual cap. For charging	6.8 kWh
CO_2 intensity	Grid power (Target)	0.35 kg CO_2/kWh
	PV system production	1,170 kg CO_2/kW

Case study: Balance of energy consump. and PV generation

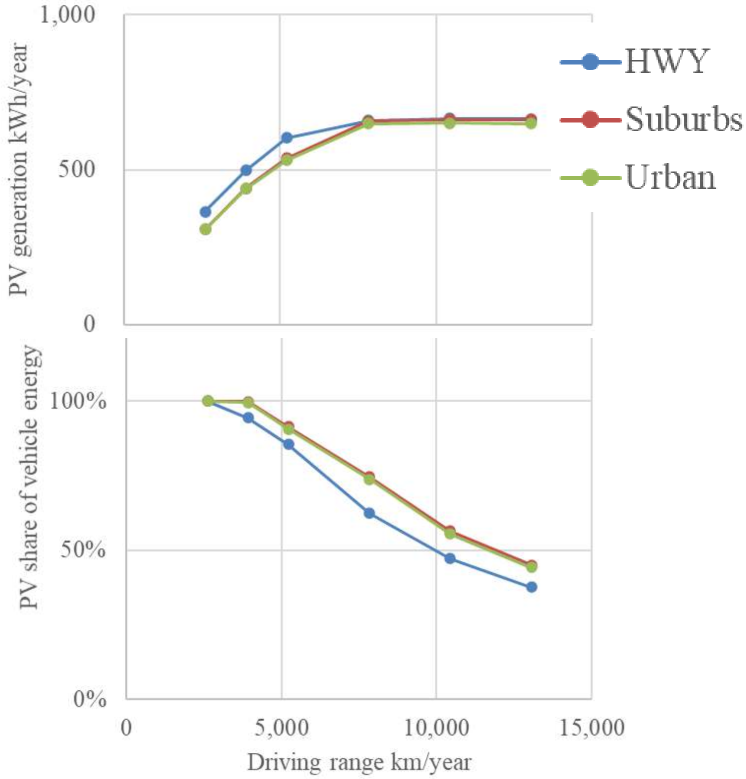
Energy model 8760h: Battery SOC management flow chart



Inputs: EV energy consumption
PV power generation
Output: Residual capacity of battery
SOC: State of Charge of battery
SOC(n+1): SOC value after 1 hour
H_0, H_1: SOC high level limit for PV charging, and Plug-in charging

Effect of driving condition on PV generation

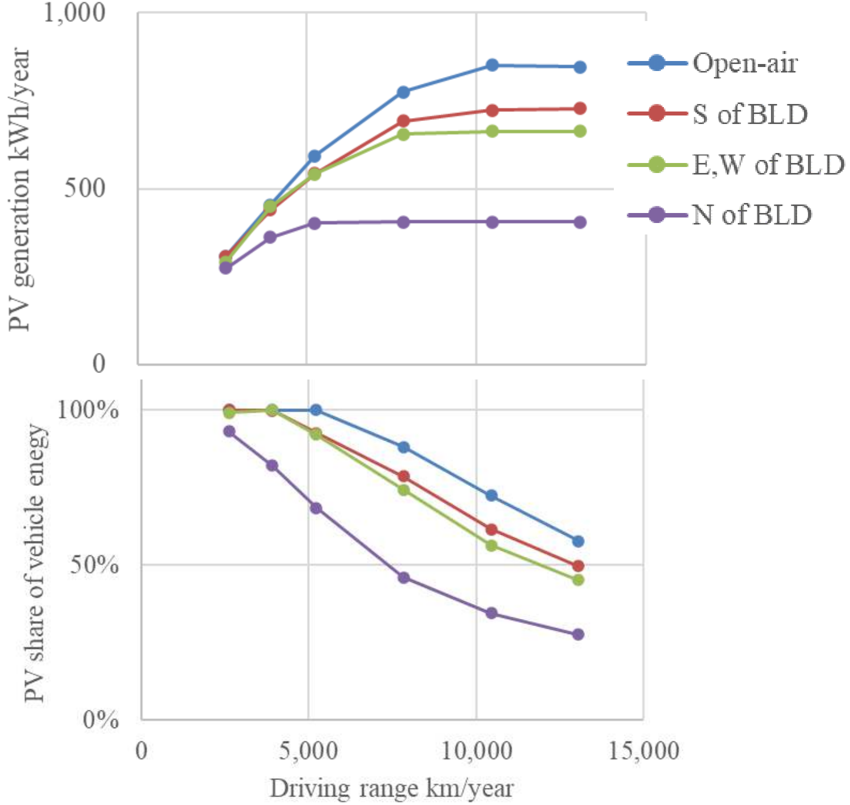
- The maximum PV generation: 660 kWh / year
- PV share of vehicle energy consumption: Over 50% under less than 10,000 km/year



- Commuting 10 – 50 km/day, 5days a week
- Annual driving range: 2,600 – 13,000 km/year
- Driving: HWY (Highway), Suburbs, Urban
- Parking: The east or west of the building
- Average shade height: HWY 10 deg, Suburbs 15 deg, Urban 30 deg

Effect of parking condition on PV generation

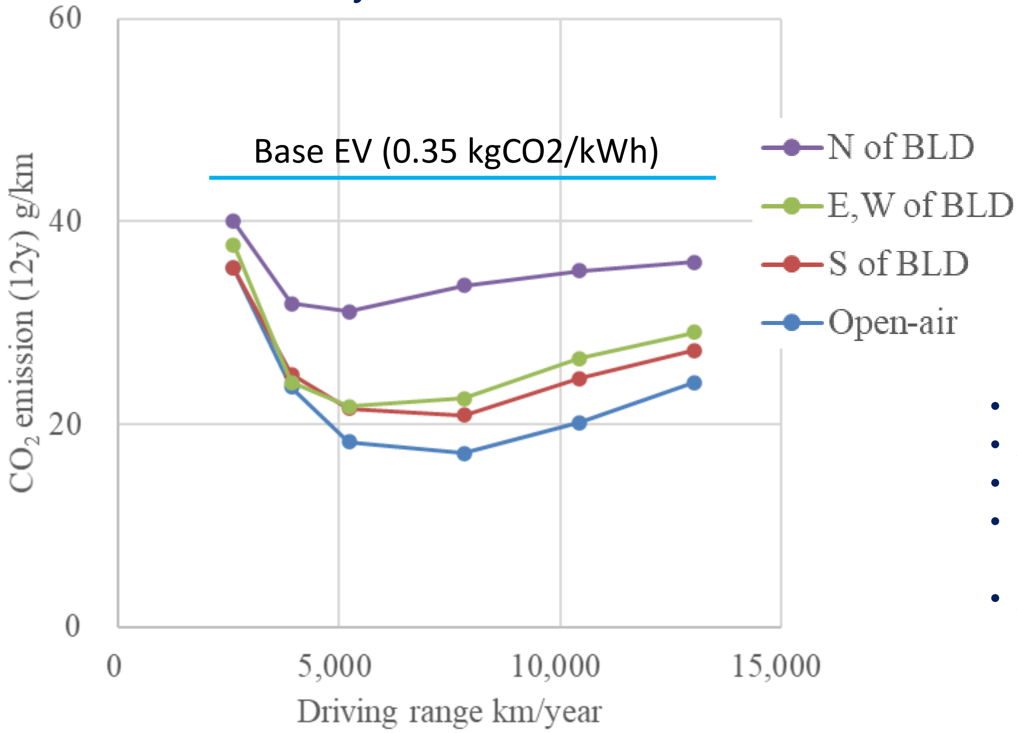
- Parking condition affects PV generation and PV share of vehicle energy consumption
- PV generation max: 850 kWh/y with open-air parking, 400 kWh/y with N of BLD



- Commuting 10 – 50 km/day, 5days a week
- Annual driving range: 2,600 – 13,000 km/year
- Driving: Suburbs, Average shade height 15 deg
- Parking: Open-air, S of BLD, E or W of BLD, N of BLD
- Average shade height: Open-air 15 deg, Near BLD 30 deg

WTW CO_2 emission of PV powered vehicle

- WTW-CO_2 emissions: Well to Wheel CO_2 emissions including the PV manufacturing process
- WTW-CO_2 emission under open-air parking is estimated to be 20 g-CO_2 / km or less in the range of 5,000 to 10,000 km / year with a 1 kW-PV.



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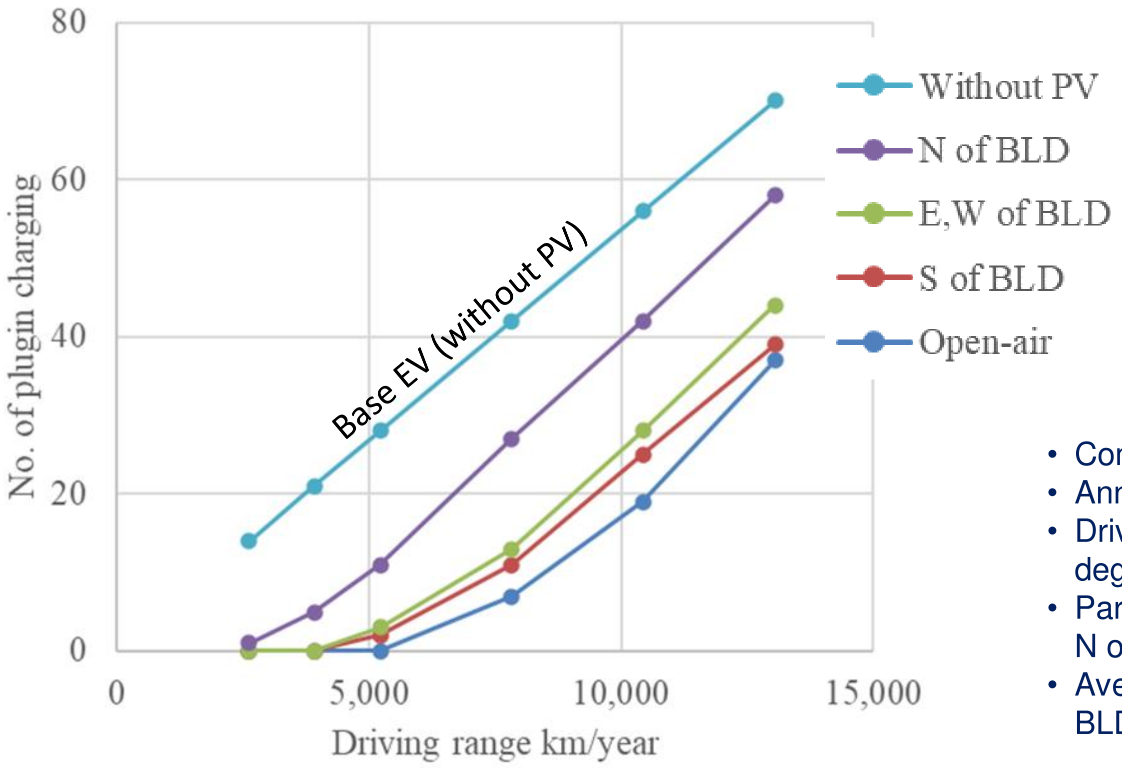
Reduction of number of plug-in charging



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- Average shade height: Open-air 15 deg, Near BLD 30 deg

Conclusions

(1)Customer survey in Japan

- Daytime: Less than 10% of cars are driving
- Parking location is major factor

(2)Vehicle test for irradiance measurement

- Irradiance ratio of vehicle and fixed point depend on where you park.

(3)Energy balance estimation

- PV-powered vehicles have the potential to reduce fossil fuel consumption, and WTW-CO2 with high efficiency PV and suitable vehicle usage.

Thank you

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