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IEA PVPS Task 17 Mobility PV: Swiss Contribution 2022 – 2024

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Zusammenfassung

Der Task 17 “PV in Transport” des Technology Collaboration Programms « PV Power Systems PVPS” der Internationalen Energie Agentur IEA wurde im Oktober 2019 gestartet. Die Schweiz wird durch Urs Muntwyler (Dr. Schüpbach & Muntwyler GmbH) vertreten und seit Programmbeginn aktiv dabei. Der Task 17 "PV in Transport» konzentriert sich auf mögliche Beiträge der Photovoltaik im Verkehrsbereich und das in diesem Bereich erwartete Marktpotenzial. Zum Task 17 trugen in den vergangenen vier Jahren über 30 Teilnehmende von 20 verschiedenen Organisationen aus 11 Ländern bei. Aufgrund des grossen Interesses und des Potentials der Anwendung wurde der Task 17 bis 2024 verlängert und das Arbeitsprogramm entsprechend aufgestellt.

Der Schweizer Beitrag in den Jahren 2022-2024 hat einen inhaltlichen Schwerpunkt im Subtask 3.2. «Business models and market diffusion of VIPV/ VAPV». Verantwortlich für den Subtask 3.2. ist Urs Muntwyler, insbesondere für die Erstellung eines Business Plan für VIPV. Mit diesem Business Plan soll gezeigt werden, wie VIPVs positioniert werden können. Daraus kann auch ein Mengengerüst abgeleitet werden. Zusammen mit dem Energieeinspar- und Substitution - Potential ergeben sich dann die relevanten Werte im Energiebereich.

Im Projektjahr 2022 war ein Schwerpunkt das Motivieren von PV-Forschenden in der Schweiz für das VIPV-Anwendungssegment. Dazu wurde das PV Forschungslabor SUPSI in Mendrisio besucht, wo ein gewisses Interesse besteht an der Messung der VIPV - PV Systeme. Auch wurden die Kontakte mit dem CSEM in Neuenburg intensiviert, welches Forschungsprojekte bearbeitet im Bereich leichter gebogener PV-Strukturen, was für VIPV Anwendunge die gefragte Kompetenz ist.

Relevant ist auch, dass seit Sommer 2021 eine IEC Arbeitsgruppe PT 600 an der Normierung der Nominalleistung und des Energieertrags von VIPV arbeitet. Urs Muntwyler ist Teil dieser Arbeitsgruppe. Aktuell werden technische “Round Robin» Messungen durchgeführt. Nach Messungen in Asien werden Messungen nun auch in Europa gemacht. Die IEC Arbeitsgruppe PT 600 wurde an der TK 82 Normengruppe von Electrosuisse vorgestellt und der Stand der Normarbeiten diskutiert. Dieser Austausch wird 2023 fortgesetzt.

Summary

Task 17 "PV in Transport" of the Technology Collaboration Program " PV Power Systems PVPS" of the International Energy Agency IEA was launched in October 2019. Switzerland is represented by Urs Muntwyler (Dr. Schüpbach & Muntwyler GmbH) and has been actively involved since the start of the program. Task 17 "PV in Transport" focuses on possible contributions of photovoltaics in the transport sector and the market potential expected in this area. Over 30 participants from 20 different organizations in 11 countries have contributed to Task 17 over the past four years. Due to the great interest and potential of the application side of the program, Task 17 is extended until 2024 and the work program was set up accordingly.

The Swiss contribution from 2022-2024 has a content focus in Subtask 3.2. "Business models and market diffusion of VIPV/ VAPV". Urs Muntwyler is responsible for Subtask 3.2 and in particular for the preparation of a business plan for VIPV. This business plan will show how VIPVs can be positioned. From this, a quantity structure can also be derived. Together with the energy saving and substitution potential, this will then result in the relevant values in the energy sector.

In the project year 2022, one focus was to motivate PV researchers in Switzerland for the VIPV application segment. For this purpose, the PV research laboratory SUPSI in Mendrisio was visited, where there is some interest in measuring VIPV - PV systems. Contacts were also intensified with the CSEM in Neuchâtel, which is working on research projects in the field of light curved PV structures, which is the competence in demand for VIPV applications.

It is also relevant that - since summer 2021 - an IEC working group PT 600 has been working on the standardization of the nominal power and the energy yield of VIPV. Urs Muntwyler is part of this working group. Currently, technical "round robin" measurements are being carried out. After measurements in Asia, measurements are now also being made in Europe. The IEC working group PT 600 was presented at the TK 82 standards group of Electrosuisse and the status of the standard work was discussed. This exchange will be continued in 2023.

Contents

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Abbreviations

IEA	International Energy Agency
DSM GmbH	Dr. Schüpbach & Muntwyler GmbH
PV	Photovoltaics
GHI	Global Horizontal Irradiation
kWh	Kilowatt hours
EV	Electric Vehicle
LEV	Light Electric Vehicle
ELCV	Light Electric Commercial Vehicle
VIPV	Vehicle Integrated Photovoltaics

1 Introduction

1.1 Background information and current situation

The IEA PVPS Programme (http://www.iea-pvps.org) is one of the largest Technology Collaboration Programmes within the framework of the International Energy Agency (IEA). The IEA PVPS has 31 members worldwide (most members are countries and industry associations) and covers approximately 90% of the photovoltaic activities worldwide (research, production, and installation). Cooperation is carried out on a variety of relevant topics in the form of various “Tasks;” eight of which are currently active.

Task 17 “PV and Transport” focuses on possible contributions of photovoltaic technologies to transport, as well as the expected market potential of photovoltaic applications in transport.

The Task was started in October 2019 at a Workshop organised by Bern University of Applied Sciences BFH in Burgdorf, Laboratory for Photovoltaic Systems (PV Lab) then directed by Prof. Urs Muntwyler (now Prof. emer.). Phase I of the Task ended in 2021 with an extension until 2022. More than 31 participants from over 20 different organizations in 11 countries participated in Task 17 in 2022. Due to the exciting results and anticipated promising future results, the Executive Committee of the PVPS task approved Phase II of Task 17 in the end of 2021.

2 Purpose and Workplan Task 17 2022-2024

The second phase of the Task 17 started in November 2021 and goes over 3 years up to the end of 2024. The task leader is still Keiichi Komoto from Japan, new deputy task leader is Prof. Manuela Sechilariu from France.

2.1. Purpose of Task 17

The purpose of Task 17 in Phase II (from 2022-2024) is[1]:

Goals
Deploy the usage of PV in transport, which will contribute to reducing CO_2 emissions in the transport sector and will enhance PV market expansions.
Objectives

- Clarify the expected benefits and requirements for PV-powered vehicles.
- Propose directions for the deployment of PV-equipped charging stations that serve as infrastructure.
- Identify barriers and solutions in the context of the requirements for both applications.
- Estimate the potential contribution of PV in transport.
- To realize the above objectives in the market, accelerate communication and ongoing activities with stakeholders like the PV industry and transport industry.

The main goal of Task 17 is to deploy “PV usage in transport”, which will contribute to reducing CO_2 emissions of the sector and enhancing PV market expansion.

2.2. Workplan 2022-2024

The Task 17 Workplan for 2022-2024 is a continuation of the Workplan in Phase I, with some amendments based on the work in Phase I:

Subtask 1: Benefits and requirements for PV-powered vehicles
Activity 1.1: Overview and recognition of the current state-of-the-art of PV-powered vehicles

Activity 1.2: PV-powered passenger cars
Activity 1.3: PV-powered light commercial vehicles
Activity 1.4: PV-powered heavy-duty vehicles
Subtask 2: PV-powered applications for electric systems and infrastructures
Activity 2.1: Overview and recognition of the current state-of-the-art of PV-powered EV charging infrastructure
Activity 2.2: Requirements, barriers, and solutions for PV-powered infrastructure for EV charging
Activity 2.3: Possible new services associated with the PV-powered infrastructure for EVs charging (V2G, V2H)
Activity 2.4: Societal impact and social acceptance for PV-powered infrastructure for EVs charging and new services
Subtask 3: Potential contribution of PV in transport
Activity 3.1: Resilience by PV and vehicles
Activity 3.2: Business models and market diffusion of VIPV / VAPV
Activity 3.3: Possible contributions and deployment scenarios for 'PV and Transport'
Subtask 4: Dissemination
Switzerland is participating in 1.1. and in 1.2.1. (Technical requirements of VIPV) / 1.4. / 3.1. / 3.2. and in 4.
Switzerland is the only contributor to Subtask 3.2. "Business models and market diffusion of VIPV / VAPV" and the Subtask leader, as business models are not a common expertise among the more technically oriented participants.

2.3. Task 17 Meetings

Two Meetings were organised in 2022:

Spring 2022: INES (Le Bourget / France) **-** Urs Muntwyler attended.

November 2022: Nagoya (Japan) - Urs Muntwyler participated via Zoom.

Both Meetings were scheduled for 3 days to allow participants from Australia, Asia, and Europe to participate simultaneously. Hence, the Meetings started at 5.30 AM (Swiss time) and sometimes lasted until 12 PM. All Meetings were well organized, very informative and interesting. The number of participants varied over the 3 days but was normally about 30. Urs Muntwyler participated in all three 3 Meetings, and over the entire period of duration of 3 days. Urs Muntwyler also gave presentations reflecting the current state-of-the-art in the development of the business plan and the diffusion of VIPV.

Spring 2023: Diffusion of new technologies - VAPV / VIPV.

Fall 2023: Business plan for VAPV / VIPV - Diffusion of Innovation.

3 Collaboration in Subtasks and Methods

3.1. Collaboration in the subtasks

The collaboration in the Subtasks 1.1. and 1.2.1. (Technical requirements of VIPV) / 1.4. / 3.1. and 4 is done by using the existing experiences in the field. Additional information will be collected jointly with the NGOs in the field.

3.2. Content and goal of the business plan

The Subtask 3.2. will deliver a “Technical report on market diffusion of VAPV / VIPV, response from producers and various users, and expected business models and success factors for the marketing of VAPV / VIPV” in 2023/ 2024.

The preliminary title of the report is: “Business models and market diffusion of VIPV / VAPV - scope and contents”:

- Diffusion model of business models of VAPV/ VIPV
- Develop the market diffusion model
- Identify the competitive advantages
- Analysis of questionnaire filled-in by users
- Case study on business cases of VAPV / VIPV
- Case study of VAPV / VIPV passenger cars realized since 1960 and new ones
- Case study of commercial VAPV / VIPV cars (trucks / busses / commercial cars)
- Identification of the most important factors for these users
- Market diffusion on VIPV / VAPV
- Customer benefits for the customer groups according to the market diffusion model for passenger cars and commercial cars

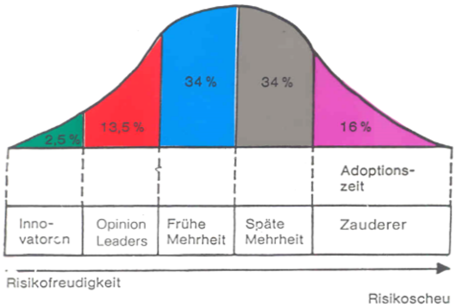
Summary: Requirements, barriers, solutions, and figures for the marketing of PV powered vehicles

3.3. Methods used for the development of the business plan

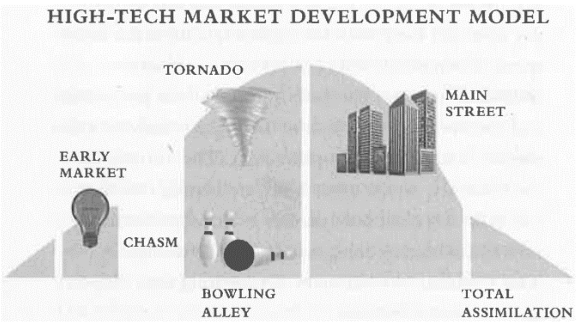
The business plan has three main parts:

- Diffusion of an innovation - the VIPV
- Crossing the chasm - entering the mass market
- Customer decision process

The book underlying the analysis of innovation diffusion is Professor Everett Rogers’s volume on «Diffusion of Innovations[2]». This diffusion theory was developed in the last 100 years. Having been very popular in the 1940s it was used in many different fields including social behavior in developing countries. It a novelty enters the market and gains markets shares.



Diffusion of Innovation (“Rogers Curve”)



Crossing the Chasm (Geoffrey A. Moore)

The “crossing the chasm” theory by Geoffrey A. Moore[3] demonstrates the challenges in the transition from the “innovator + opinion leader” market into the mass market. This transition needs a new approach in the attitude of the producer and especially in the product. Many novelties and especially their companies fail in that regard.

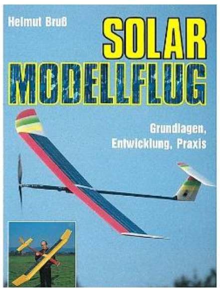
In the mass market, the more traditional aspects of marketing gain more momentum as is explained by the “Competitive Customer Advantage” (CCA) concept developed by Professor Backhaus from the University of Münster, Germany. It urges the importance of a few distinct customer advantages over the competing solution in the sales process.

All the methods described in this Section have extensively been proven and applied by Urs Muntwyler, e.g., in the “Verkaufserfolg für erneuerbare Energien” sales course of the PACER (Program accelera-tion énergie renouvelable) program of the Bundesamt für Konjunkturfragen in 1995. Moreover, the suitability for all methods was highlighted in 1999, in a study on an electric van of Daimler Chrysler. Furthermore, all methods were successfully deployed in the company Solarcenter Muntwyler AG owned by Urs Muntwyler, i.e., before the company was sold in 2010.

4 Activities and First Results

4.1 Historical development of VIPVs

Electric vehicles with PV were first demonstrated in the 1960es; specifically, it was an electrified Ford T with some PV cells on its roof. While the price / performance ratio was beyond market reality, the Ford T provided a little glimpse into the future. The applications following PV applications in vehicles were the solar generators for satellites.



Electrified Ford T with PV models

First PV model (supported DARPA/ US)

Popular book on PV

This led to prototypes for electrified aircraft. The first model with solar cells was built in the US and was financially supported by DARPA (military agency) in the US. The lead acid batteries at that time were too heavy for such airplanes, and “solar planes” only went popular in the early 1980s. With new batteries like Ni/Cd and later NiMh (and now Lithium) this changed drastically. Solar planes disap-peared and a huge range of very powerful solutions based on lithium were established in the industry. In Switzerland and other countries worldwide, lightweight EVs and PV charging stations for EVs were promoted by solar car races in the 1980es. The new applications of solar energy became very popular, and it is hence no surprise that some of the racing solar cars from the 1980s and the 1990s survived.

The image in the middle shows the solar gasoline charging station of the «Tour de Sol» solar car race in 1986 with VIPVs (it is the first public charging station PCS from AEG). The other images show VIPS (left) and a grid-connected PV charging station (right) of the «Tour de Sol» race in 1987.

The images below show the VIPV used by the British inventor Alan Freeman in the early 1980s (left), a Horlacher City VIPV from the early 1990s (middle), and a VIPV from Kyocera in Japan from the early 1990s (right).

4.2 Diffusion of innovation - Rogers' curve and the chasm for VIPVs

VIPVs are a novelty. Since the «Tour de Sol» years in the late 1980s, dozens of companies tried to enter the market. They all failed in the "innovator" and "opinion leader" phase of the market introduction. Today, the automotive industry is in a disruption because of the electric car, and the jump to VIPVs is now quite short and hence, it is of no surprise that SOME initiatives on the «VIPV approach» have started.

4.3 VIPVs for innovators and opinion leaders

4.3.1 Examples of VIPV initiatives and most popular VIPVs today are given below (see images below: Sion Sono Motors (left), Lightyear (middle), Aptera (right)). It's a nice picture of an innovative new market. However, the most probable outlook is a declaration of bankruptcy soon. Yet, the VIPV initiatives described below demonstrate what is technically possible and thus both stimulate the VIPV avenue in the market and car producers.

- **"Sion Sono Motors" (Germany):** Proposed a compact VIPV about six years ago at the cost of 29'900 €. Sono motors worked with pre- reservation and a low level of investments - as this was popular after Tesla demonstrated how this could work in the "innovator + opinion leader" customer group. Unfortunately, the young, enthusiastic, and inexperienced team failed several times with their announcements for delivery times, prices etc. They underestimated the obstacles and needed cash flow on the way towards mass production. Due to their announ-cements, the car design, and the price of the car, it looks as though they jump directly into the "mass market". This is a very unrealistic approach.

- **Lightyear (NL):** This aerodynamic sport car just entered the market. It has a big PV coverage and is thus very efficient. The "Lightyear" follows the Rogers' curve. It is available in limited numbers and very expensive with a price in the range of 250’000 €. This should be acceptable for the innovator customer group. The production number is limited to about 250. After the first lightyear model was launched, a much cheaper model is announced with a price of 34’000 €.

- **Aptera (USA):** The Aptera is a 3-wheeler lightweight model from California. The first attempt of the company was in 2012, then the company went bankrupt. Now they try it once more. The design, price etc. is suitable for “innovators” but could also be attractive to some customers in the “opinion leader” group. Yet, it is hard to guess that this model could go into the “early mass market”. A first delivery at a price of 25’900 € is announced for end of 2022 in the US.



Sion Sono Motors Lightyear Aptera

4.4 Customer benefits of VIPV

The five customer benefits in the market are:

- **P**rofit Financially advantageous - a good deal
- **P**eace No hassle with the product
- **P**leasure To have and use the product
- **P**ride Prestige for the user
- **+**: **Social responsibility** something for the world of tomorrow

VIPVs offer advantages in all five aspects. Profit is not so big as the savings are limited due to the efficiency of the electric drive train and the price of electricity in most countries. But this could change in some markets. Peace is only relevant in the context of using less charging at a gasoline station. But for an EV user this is not a big deal anyway. Pleasure works especially for the “innovator + opinion leader” as a VIPV is something totally new. It is not astonishing that some of the first Tesla customers in Switzerland just reserved their “Sono Motors” and even “Aptera”. The high price of the “Lightyear” limits the car to a small number of owners. “Pride” is a customer advantage, like the “Pleasure”, and they both demonstrate the “social responsibility”. Unfortunately, such customers in Switzerland also want to avoid all car drives or are a member of a car sharing company. But this is not a relevant alternative in other mid-European countries or in the US. In Japan, though, the energy autonomy could be a very strong customer advantage as the Japanese intend to use such a car as an uninterruptible power supply (USP) in case of catastrophes like earthquakes, etc.

4.5 VIPVs for mass markets

There are no VIPVs for the mass markets. Toyota offered a Prius version with a small PV roof, but it was not very visible. It is the same issue with the most expensive version of the Hyundai Ionique 5. The rumours say that the PV roof delayed the delivery of the car for months. This happened in a period of shortage of critical electronic components. Car producers are still occupied with the growing demand for pure electric vehicles. In such a situation, a VIPV doesn't make sense. But this will change. The efforts of Toyota in the development of high efficiency solar cells over 30% pave the way!

4.6 VIPVs for niche markets

Before the mass-market, there are the markets niches. Here we can see PV modules in growing numbers. First applications are recreational vans RVs and boats. The customer advantage is given in both applications. The price is not important and is way below the price of an RV or a boat. The next mobile applications are gliders. This application increasingly needs electricity for radio communication, navigation aids like transponders, or FLARM (an anti-collision device that uses GPS and radio transmitting). Special PV modules integrated in the fuselage or below the canopy helps to provide a reliable power supply.

Glider with PV Some trucks with internal combustion engines with PV

The next application will be trucks with additional electricity consumption like fridges for critical goods, climatization, etc. PV modules produce the electricity at a much lower price than a generator of the truck. A further advantage is that, in the case of the cooling application, no motors are needed.

VIPVs will be successful in the mass market if battery-driven electric vehicles are established and when a VIPV offers new customer advantages. Our sophisticated guess is that this is expected to happen at the end of this decade.

5 PV Preferred Charging of EVs

The efforts in the PV preferred charging are mainly undertaken in Subtask 2. New charging methods such as V2G or V2H are still a very new approach. Pilot- and demonstration activities are numerous, even in Switzerland. Outside Switzerland, the efforts are even much bigger, an exception is the charging of busses. The activities and sales success of the company Hess AG Bellach (SO) demonstrate the worldwide leading position of this company.

Increasingly, more and more countries also come forward with regulations, which make PV on carports mandatory.

6 PT 600 IEC Working Group

The Japanese delegation of the IEA TCP PVPS Task 17 made the initiative for first steps into a new IEC norm for VIPV. Here, the nominal power and energy yield for a vehicle covered with solar cells on several sides is an open question. The curved modules used for VIPV make THE difference.

The Japanese scientist Kenji Araki (also a member of the IEA TCP PVPS Task 17) is the leader of the group for "International standardization on vehicle integrated photovoltaic (VIPV). There is currently a round robin test campaign being carried out. There are no European and US institutes involved. The curved modules have a 5D uniformity (3D space + 2 angles).

The working group called PT 600 runs under the IEC principles code of conduct. Since November 2021, 49 participants (2 from Switzerland being Urs Muntwyler / Dr. Schüpbach & Muntwyler GmbH + Antonin Faes / CSEM) are in the working group. The participants meet once a month for one hour. Urs Muntwyler is used as the link between the history of VIPV («Tour de Sol», etc./ P- und D Leicht -Elektromobile) and the IEA TCP HEV (in which Urs Muntwyler served as the Chair for 20 years).

7 Dissemination

In parallel to the 2 workshops per year, which were slightly more complicated due to the Corona situation, a PV research conference on "PV in Motion» is now also organised. The first Conference was held (in hybrid mode) in December 2021 in Freiburg im Breisgau (Germany). Urs Muntwyler gave an oral presentation on «Vehicle integrated PV development in the last 40 years» and presented a Poster on «EV as a new driver for PV».

In February 2023, the 2nd Conference «PV in Motion» Conference will be held in s'Hertogenbosch (NL). The contribution of Urs Muntwyler on "Towards a business plan for Vehicle Integrated PV (VIPV) and PV Charging Stations (PVCs)" was invited as an oral contribution.

Urs Muntwyler also made efforts to invite the «PV in Motion» Conference 2024 to Switzerland. The efforts were successful, and the CSEM will host the Conference in Neuchâtel in March 2024. This will be a good opportunity to promote the VIPV topic in Switzerland.

In the context of Subtask 4 "Dissemination", we already published some of our results and conclusions at various Conferences and in media as listed below.

- 38th EU PVSEC 2021, Online Event, September 2021: "SimZukunft"
- 16th EU EVER, Online Event, April 2021: "PV Energy Yield Measurements of Electric Vehicle and Electric Vehicle Charging Station"
- Oral Presentation and one Poster presentation on the "PV in Motion" Conference in December 2021
- Oral Presentation at the WPVSEC Australia, December 2021
- Oral Presentation at the TCS Mobility Forum in September 2022, Bern
- Oral Presentation of results on public conferences and speeches by Urs Muntwyler (2022)

8 Outlook

The IEA Task 17 is in its first year of Phase II. The workplan is established, the collaborations within the task run well, in spite of the complications with regard to Covid restrictions.

The outlook for VIPVs looks better than in the past, which is due to the circumstances in the energy sector. The interest of the mainly Japanese automotive industry is interesting. Technical challenges are still waiting, like the integration of solar cells in a car shelf, the nominal power, and the energy yield in the different situations.

The different customer benefits of a VIPV are not well understood. Customer benefits can vary from country to country, region to region. This is a topic needing attention.

The first VIPVs are still concept cars and show what could be done. Whether or not they have a chance to survive is open. The car industry is fully occupied with the delivery of standard battery electric vehicles. For them, the VIPV road is still ahead.

The contribution of VIPVs to the energy supply of a country is an open point. This and the combination with solar carports are important avenues of further research.

PV preferred charging is a must and in some of the regions/countries/states of Switzerland an obligation for new and sometime existing parking lots. Technically there are no minor obstacles, and the financial situation has improved due to the situation in the electricity market due to geopolitical disturbances.

9 Appendix / Reports

- Presentations from the IEA Task 17 meetings in Fall 2021/ Spring 2022 and Fall 2022 (3 PDFs)

- State-of-the-art and Expected Benefits of PV-powered Vehicles, 155 pages, 2021, IEA TCP PVPS Task 17/ ISBN 978-3-907281-15-4

- PV Powered Electric Vehicle Charging Stations – Preliminary Requirements and Feasibility Conditions of PV-Powered Electric Vehicle Charging Stations: Preliminary Requirements and Feasibility Conditions Report IEA-PVPS T17-02:2021 December – 2021 ISBN 978-3-907281-26-0

10 References

[1]Status report: Task17 'PV and Transport' Keiichi Komoto (MHRT, Japan) & Toshio Hirota (Waseda University, Japan), November 2021
[2] Everett M. Rogers, Diffusion of Innovations, 5th edition, 2003
[3] Geoffrey A. Moore, Crossing the Chasm, 3rd edition, 2014

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