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A Future Brighter than the Sun: Improving Public Support for Solar Energy Early-stage Startups in Lithuania

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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ABSTRACT OF THESIS submitted by:
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To reach net-zero of GHG emissions and limit the global temperature rise to 1.5 °C, the increased capacity of clean energy is needed. One of the main drivers of clean energy is solar energy. Despite the price reduction, solar energy still lacks innovation to increase efficiency and applicability. Solar energy innovation is essential for countries with a low gross domestic product and high energy dependency, such as Lithuania. However, building solar energy innovation requires resources and long-term support in the early stage of development, often lacking from the private sector due to the high risk and long-time of return of investments. This thesis advances the understanding of the public support of the early-stage solar energy startups. It provides policy recommendations for improving the public support mechanisms in the upcoming European Cohesion Policy and European Structural and Investment Funds (ESIF) programming period (2021-2027) to increase solar energy innovation capacity. Using a pilot project, this thesis seeks to answer three research questions: (1) What kind of support for the early-stage solar energy startups exist in Lithuania, and how can it be improved? (2) How can the public financial support for solar energy early-stage startups be improved based on the needs of startups? (3) How can the public support mechanisms for the early-stage solar energy startups be improved for the upcoming ESIF programming period? The thesis concludes that Lithuania‘s public support for solar energy early-stage startups is limited due to the high eligibility criteria, lack of mentorship programs, and collaboration spaces.

Keywords: early-stage startups, solar energy, clean energy, innovation, Lithuania, EU financial support

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List of Abbreviations

R&D&I	Research, development and innovation
R&D	Research and development
EU	European Union
IRENA	International Renewable Energy Agency
EV	Electric vehicles
AI	Artificial intelligence
IoT	Internet of things
VC	Venture capital
PE	Private equity
VoD	Valley of death
ROI	Return of investment
GHG	Greenhouse gasses
OP	Operational program
SMEs	Small and medium-sized enterprises
EBIT	European Business Initiative on Taxation
IPCC	International Panel on Climate Change
SDGs	Sustainable Development Goals
PV	Photovoltaics
IEA	International Energy Agency
GDP	Gross domestic product
CSP	Concentrated solar power
ESIF	European structural and investment funds
HT	High temperature
OTEC	Ocean thermal energy conversion
CCS	Carbon capture and storage
RES	Renewable energy sources
DoI	Diffusion of innovation
MVP	Minimum viable product
EIT	European Institute of Innovation & Technology
PoC	Proof of concept
CEO	Chief executive officer
PPPs	Public-private partnerships
EPO	European Patent Office
EIB	European Investment Bank
LNG	Liquefied natural gas

1. Introduction

1.1 Background

Global demands for energy produced from renewable energy sources are increasing due to the negative environmental impacts of non-renewable energy sources (i.e., fossil fuels). The excessive burning of fossil fuels has resulted in the depleting of natural resources and increase in greenhouse gas (GHG) emissions, which are responsible for rising global temperatures (Lu *et al.* 2020). The International Panel on Climate Change (IPCC) (2018) report suggests that global surface temperatures will continue to rise if GHG emissions continue to increase (Collins *et al.* 2013). To reduce the risk of temperature increase, governments and international organizations aim to implement policies and response actions to lower fossil fuel emissions. For example, in the Kyoto protocol (2005), at least 55 states committed to reducing their GHG emissions, and in the Paris Agreement (2015), which was signed among 196 state partners, states committed to reduce GHG emissions in order to halt the temperature increase at 2 degrees Celsius above pre-industrial levels (Lu *et al.* 2020). Additionally, the United Nations General Assembly adopted 17 sustainable development goals (SDGs) in 2016, where SDG 7 aims to "Ensure access to affordable, reliable, sustainable and modern energy for all" and "guarantee a 17% share of renewable energy in total energy consumption" (UN Department of Economic and Social Affairs 2020).

The European Union (EU) aims to become carbon neutral by 2050 (European Commission 2020). This ambitious goal requires a transformation of the EU's entire energy system (which accounts for 75% of the EU's GHG emissions), and an increase in renewable energy capacity (European Commission 2020). Two strategies are present on the EU's agenda: a recovery package (i.e., the Next Generation EU) and the European Green Deal. In both these strategies, solar energy plays an important part.

According to the International Energy Agency (IEA) (2020a), solar energy is the primary driver of renewable energy growth. In 2019, solar PV generation increased 22% (+131 TWh) and represented the second-largest absolute generation growth of all renewable energy, slightly behind wind energy and ahead of green hydrogen (IEA 2020b). Despite the rapid increase and cost reduction of solar energy generation technologies, solar energy development lacks efficiency in maintenance and applicability. For this reason, innovation is needed to improve integration of smart technologies into solar energy technologies (IEA 2019).

The development of solar energy innovation plays a vital role in the economies of EU Member States with a low gross domestic product (GDP) and a high percentage of energy dependency. One of those countries is Lithuania. Lithuania's GDP is one of the lowest in the EU (48,43 billion euros), and its energy dependency accounts for 78.3%, considering oil, gas, and coal (Bluszcz 2017). The Lithuanian government predicts that in coming years, the market for new products and services will expand in the Lithuanian energy sector due to increasing building renovation programs, the rising efficiency of manufacturing companies, and promoting the use of renewable energy resources (Ministry of Energy of the Republic of Lithuania 2020). These changes will broaden the vast potential for investment in the energy sector, developing new resource capacity and encouraging well-functioning energy innovation startup ecosystem[1]. A well-functioning energy innovation ecosystem will improve the conditions for local producers and researchers to develop and strengthen the country's innovative products. In this case, a part of the necessary investments could remain in Lithuania, which would contribute to strengthening of the country's economy (Ministry of Energy of the Republic of Lithuania 2020).

[1]Startup ecosystem – a network of business called ecosystem because of its complex interdependent parts (Hubbub Labs 2017).

1.2 Problem Definition

New possibilities for innovation development in the solar energy sector emerged after Lithuania joined the European Union (2004) and had a chance to use European Structural and Investment Funds (ESIF) for supporting early-stage startup companies. The process of turning an idea into an innovative product requires entrepreneurs to secure long-term investments. Startups who fail to secure funding suffer from funding shortages, also known as the "valley of death" (VoD) (In *et al.* 2020). Investing in early-stage Research, development, and innovation (R&D&I) startup companies for Venture Capital (VC) is extremely risky because of the low success rate of startup companies. For this reason, public financing (governmental support) plays a vital role in sustaining the company until the idea is developed and can attract VC, private investors, or clients. ESIF are the leading clean energy and solar energy innovation public financial support in Lithuania (Interviewee 8 2021). However, the effectiveness of ESIF dedicated to encouraging clean energy and solar energy innovation are not well researched in Lithuania, and it is still unclear how public support mechanisms can be improved to assist early-stage solar energy startups.

1.3 Research Aims and Objectives

This thesis aims to draw policy recommendations on how the public support mechanisms can be designed to better meet the needs of early-stage solar energy startup companies for the upcoming Cohesion Policy and ESIF programming period (2021-2027) based on the following objectives:

- To understand the importance of public support for early-stage solar energy startups and the startups needs.
- To analyse how much was invested in solar energy early-stage startups in Lithuania in the previous ESIF programming period, analyze if the investments were adequote for energy early-stage solar energy startups and draw the lessons learned.

- To understand the current support oportunities and gaps, and suggest support improvements.

1.4 Research Questions

The following questions intend to help conduct research and provide policy recommendations to improve the solar energy innovation support in Lithuania:

1. What kind of support exists for early-stage solar energy startup in Lithuania?
2. How can the public finance support for solar energy early-stage startups be improved based on the needs of startups?
3. How can the public support for the solar energy early-stage startups be improved for the upcoming ESIF programming period?

1.5 Thesis Outline

This thesis is composed of Eleven chapters. Chapter One gives background on the thesis topic as well as the research aims and objectives. Chapter Two provides an overview of literature, relevant definitions and outlines of the theories used to make the recommendations. Chapter Three presents the methods used to collect data and answer the research questions. Chapter Four presents the pilot project and its challenges related to the accessibility to support. Chapter Five discusses the needs of solar energy early-stage start-ups in Lithuania. Chapter Six presents the role of government in supporting startups and available support gaps and opportunities. Chapter Seven shows the funding distribution for early-stage solar energy startups in 2014-2020 and discusses lessons learned. Chapter Eight analyses how public support can be improved in the future, based on the needs and lessons learned in the past. Chapter Nine summarises the research findings, Chapter Ten shows a discussion, and Chapter Eleven provides conclusions and policy recommendations.

2. Literature Review

To understand how the support of early-stage solar energy startup companies in Lithuania can be improved, it is essential to analyse the concepts of clean energy innovation. The concept of solar energy is usually not separated from that of clean energy in the context of innovation, and therefore funding for solar energy is usually under the umbrella of clean energy. It is also important to note that in this thesis, early-stage startups are believed to be one of the main drivers of entirely new ideas and innovations (Armada IP Capital 2019).

This chapter provides definitions, highlights the importance of investing in early-stage solar energy startups, and presents the support from the EU and Lithuania's national funds and theories that assist in defining policy recommendations.

2.1 Solar Energy Innovation in the Context of Clean Energy Innovation

2.1.1 Definition and Scope

The International Energy Agency (IEA) (2020c) defines clean energy innovation as "generating ideas for new products and production processes in the clean energy sector from development to reaching markets". Georgeson *et al.* (2016) remark that clean energy innovation definitions depend on how each region and country independently understand clean energy and innovation.

Some countries define clean energy as direct solar, wind, and hydropower energy, while other countries also include energy efficiency, carbon capture, storage, or increased deployment of natural gas (Georgeson *et al.* 2016). For example, in Germany, the definition of clean energy includes renewable energy, energy efficiency, storage technologies, carbon capture and storage, and fuel cells (Georgeson *et al.* 2016). On the other hand, the United States of America defines clean energy as solar, wind, water, geothermal, bioenergy, and nuclear energy (U.S. Department of Energy, n.d.). The way a country defines clean energy influences the budget allocated to clean energy innovation (Georgeson *et al.* 2016).

In terms of innovation, Grubler and Wilson (2014) suggest that innovation is a resource that originates from human inspiration and aims to solve the social, environmental, and economic challenges that arise from combining interrelated technology. The critical push drivers of innovation according to Grubler and Wilson (2014) are:

1. Knowledge – knowledge generation contribute to the research and development of innovation.
2. Actors and institutions – contribute to the development of innovation and shape technology life cycle.
3. Adoption and use – innovations adaptation to the market.

According to Edler and Fagerberg (2017), innovation is defined as the first commercialization of an idea, and it is classified based on the categories shown in the Fig. 1.

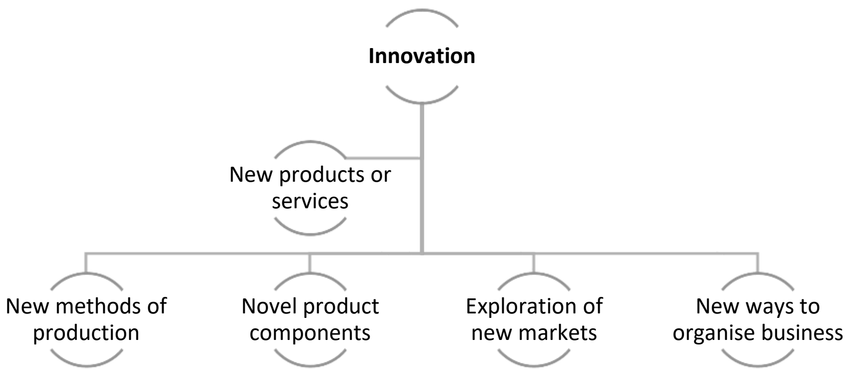

Figure 1: Classification of innovation based on Edler and Fagerberg.
Data source: Edler and Fagerberg (2017)

According to Elder and Fagerberg (2017, 4), new products or services (as shown in Fig. 1.) include technological solutions or services that contribute to clean energy's accessibility and efficiency. New methods of production involve manufacturing technologies that improve the efficiency of the production. Novel components are new technology solutions used to improve the performance of the end-use products. The exploration of a new market niche involves exploring potential demands and new business models (Elder and Fagerberg 2017, 4).

The definition of the innovation process differs. In this thesis, a basic innovation process description by Schoen *et al.* (2005) will be used. Based on these authors, the fundamental innovation steps are as follows:

1. Primary research – defines a period of a search for new knowledge. In this period, the commercialization of the product is usually not considered.
2. Invention period – a process of developing a new product. This process relates to how the knowledge can be used practically and is most like the applied research outcomes.
3. Innovation – a commercialization of invented products or services as well as marketing activities.

It is essential to highlight that Schoen *et al.* (2005) define systemic innovation as a complex process where all innovation steps are interrelated (Fig. 2.).

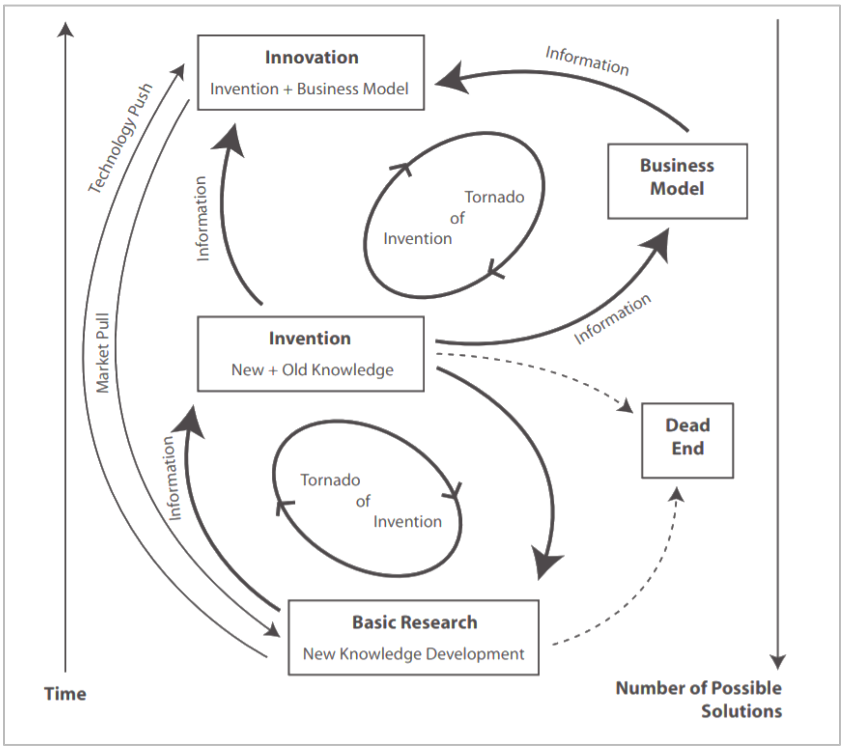

Figure 2: Innovation model.
Source: Schoen et al. (2005)

Schoen *et al.* (2005) illustrate that innovation is not a tidy process; innovation is a complex process that requires a balance between a product idea and a business concept that fills innovation gaps and opportunities, as well as working consistently in a focused manner on the product development.

The International Renewable Energy Agency (IRENA) (2019) suggests that clean energy innovation requires systemic innovation. Systematic innovation is a concept that covers innovations in four dimensions: technology, business model, market, and systems operation (IRENA 2019). Considering the definitions of systematic innovation and clean energy discussed above, the scope of clean energy innovation varies, but standard directions include energy storage, grid modernization, demand reduction, artificial intelligence (AI) and Internet of Things (IoT) integration, and new concepts of renewable energy generation (Surana *et al.* 2020).

2.1.2 Solar Energy Perspectives

This thesis focusses on systematic innovation in emerging and existing solar technologies. Based on the Eurostat data, the electricity generation capacity of solar power increased rapidly from 2010, and the cost of solar PV and CSP dropped significantly (IRENA 2020) as can be seen in Fig. 3. Fig. 4. Show a large decrease of solar PV prices. Together with increasing capacity and lower cost, the innovation in the solar energy industry became more focused on manufacturing optimisation and scale up to “push down production cost” even further (IEA and EPO 2021,15).

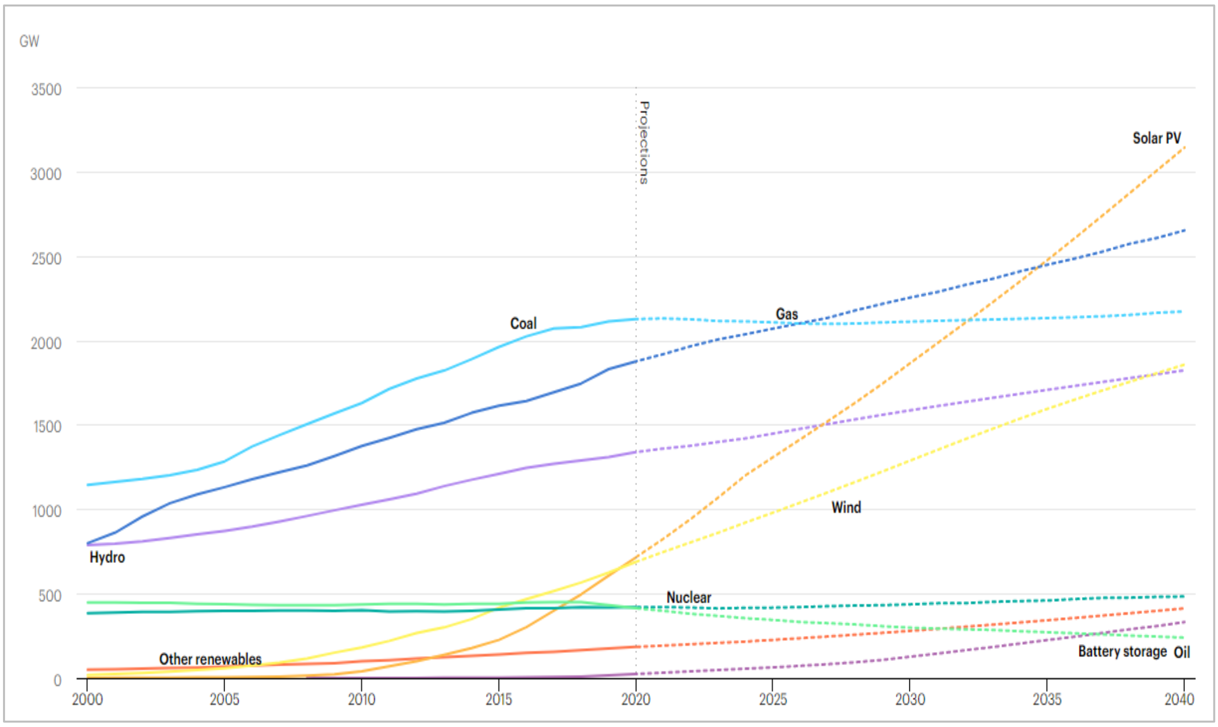

Figure 3: Electricity generation capacity by source.
Source: EIA (2020f)

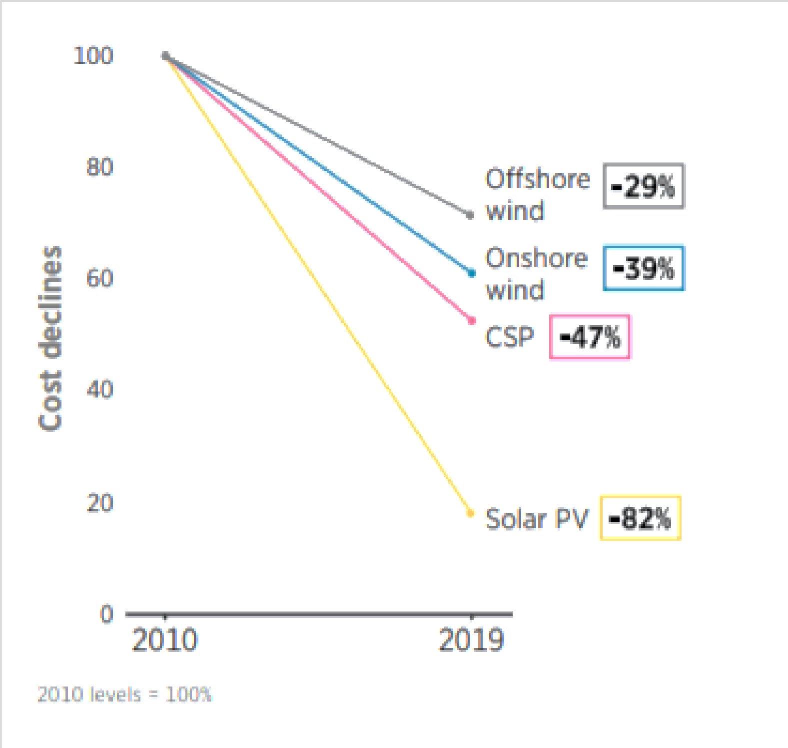

Figure 4: Cost reduction of solar PV.
Source: IRENA (n.d.)

Then after 2010, the market consolidation that appeared around the PV solar was observed. This caused the slowdown of innovative designs due to decreased incentives. Based on the IEA and European Patent Office (EPO) study (2021), the innovation in the solar energy field shifted after solar energy technologies passed phases of development. Between 2010 and 2020, annual global solar PV installations rose more than six-fold, from 17 GW to over 100 GW per year (IEA and EPO 2021). Despite the fact that solar energy technology is currently well developed and widely used worldwide, systematic innovation covering business models, installation technology, and system operations in the solar power sector (both solar PV and concentrated solar power (CSP)) needs to be improved to increase the efficiency of solar energy.

Recently, two solar energy innovation trends are emerging: new kinds of PV designs and technologies are appearing, allowing more cost-effective installation and innovation in solar generation operation management is increasing (IEA and EPO 2021).

Systemic innovations are required to solve the solar PV mounting, the cost reduction of CSP, low-cost thermal storage, and HT applications to scale up solar energy usage worldwide (IRENA 2019). Based on the IEA and EPO (2021), the innovation gap existing in solar energy supply includes concentrated PV, organic printable thin-film PV, linear Fresnel reflections for solar thermal, and mass production of thermal solar heating. It was observed that there had been a steady rise in patenting activity in organic PV cells, which are lighter, more flexible, and customizable, as well as a rising in PV mounting technologies (IEA and EPO 2021).

2.2 Financing Clean Energy and Solar Innovation

Solar energy innovation financing is often not separated from overall clean energy financing. For this reason, the financing of clean energy will be discussed first.

A research on public and private investments into clean energy innovation is limited (UN Department of Economic and Social Affairs n.d.). Although it is known that finance is critical for finding novel methods to supply energy, the investment in clean energy innovation is hazardous, uncertain, and requires long-lasting funding (Mazzucato and Semieniuk 2017).

Investors provide the primary capital for turning an idea into an innovative product. However, early-stage clean energy innovation investments are uncertain because of low success rates (Mazzucato and Semieniuk 2017). Additionally, the Covid-19 pandemic impacted and is still harming private investments in clean energy innovation (IEA 2020d). Many private investors reduced their budget dedicated to clean energy innovation, and it is predicted that the early-stage innovators will suffer most from the investment drawback (IEA 2020d). Recently many energy-related companies reported declines in R&D budgets in the first quarter of 2020, and the number of venture capital (VC) deals was also down (IEA 2020e).

2.2.1 Key Investors

Each investor in clean energy innovation has different characteristics and provides another type of funding that affects innovation development (Mazzucato and Semieniuk 2017). In addition to VC and private equity (PE), public finance plays an important role, such as the European Institute of Innovation & Technology (EIT) InnoEnergy (Fig. 5.) (Energyaccelerator.lt 2020).

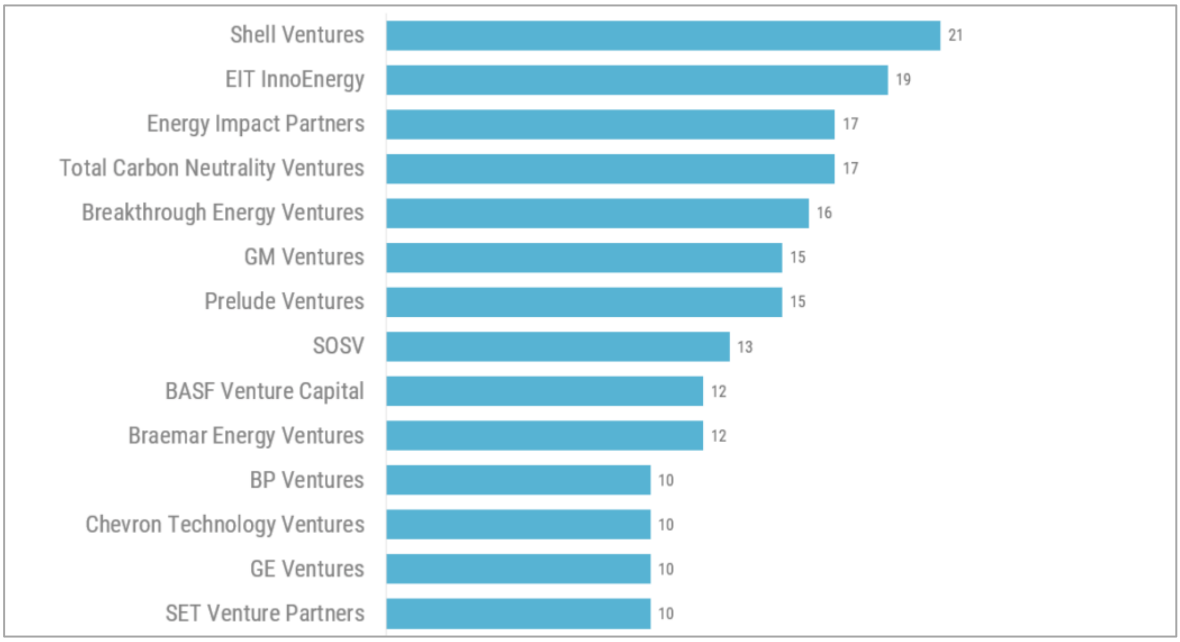

Figure 5: Top investors in renewable energy tech by unique deals.
Source: Cbinsights (2020)

According to In *et al.* (2020), VC and PE funds usually finance early-stage projects. This is because private investors aim for higher returns, which result from investing in higher-risk technologies. PE and VC are also crucial for initializing investments that assist startup companies in overcoming the valley of death (VoD) circumstances. On the other hand, In *et al.* (2020) argue that PE and VC are less likely to invest in clean energy innovation because of the long return of investment (ROI)[2]. For example, in the early 2000s, the entrepreneurs were provided with significant PE and VC funding in the US. Unfortunately, companies lost over 50% of their USD 25 billion investment because clean energy innovation required long-term

[2] Return of investment (ROI) is a ratio that illustrates the benefit that investor receives minus the investment cost (CFI n.d.).

ROI. The investment capitals are usually deployed through debts, public equity, guarantees, and hybrid instruments for more mature and lower risk requiting technologies, but there is little known on what barriers prevent potential investors from emerging and how policies can create channels between investors and entrepreneurs (In *et al.* 2020). Moreover, VC and PE investing models are rarely synchronized with clean energy innovation companies due to the lack of opportunities worldwide, low exit valuations, and a long financial liquidity[3]. In *et al*. (2020, 4) argue that VC and PE funding models are unsuited for clean energy entrepreneurs since "VC/PE funds increase their chance of gaining positive returns by investing in a large number of companies and projects, not the few capital-intensive projects that are typical of clean energy investments".

2.2.2 The Importance of Public Finance for Clean Energy Early-stage Startups

Pre-seed investments[4] are essential for entrepreneurs to strengthen the endeavors to bring technology from the laboratory to the marketplace. Based on In *et al.* (2020), when a startup company fails to form a financial alliance, the risk of failure to overcome the VoD increases (Fig. 6). In *et al.* (2020) add that the large-scale and long-term investments before clean energy technology is commercially viable are essential to scale up the primary product. Investments need to be allocated before the technology becomes commercially viable, due to the extended testing period. Also, clean energy innovation technology needs to overcome further regulatory challenges and commercial scrutiny because this technology impacts nature and human well-being (In *et al*. 2020). In *et al.* (2020) divide clean energy innovation development into five stages: research and development (R&D), demonstration and proof of concept (PoC), deployment and pilot facility, diffusion and first commercialization, and commercial maturity.

[3] Financial liquidity defines how easily assets can be converted to cash (Mueller 2021).
[4] Pre-seed investments – the first investment a company at its early stages of development (Metavallon 2018).

The VoD appears in the diffusion and first commercialization phase (In *et al.* 2020) (Fig. 6.). In this period, the investors are uncertain about the risks and reluctant to deploy investment capital at a large scale (In *et al.* 2020). The possibility of a startup falling into the VoD is highly related to the Diffusion of Innovation theory.

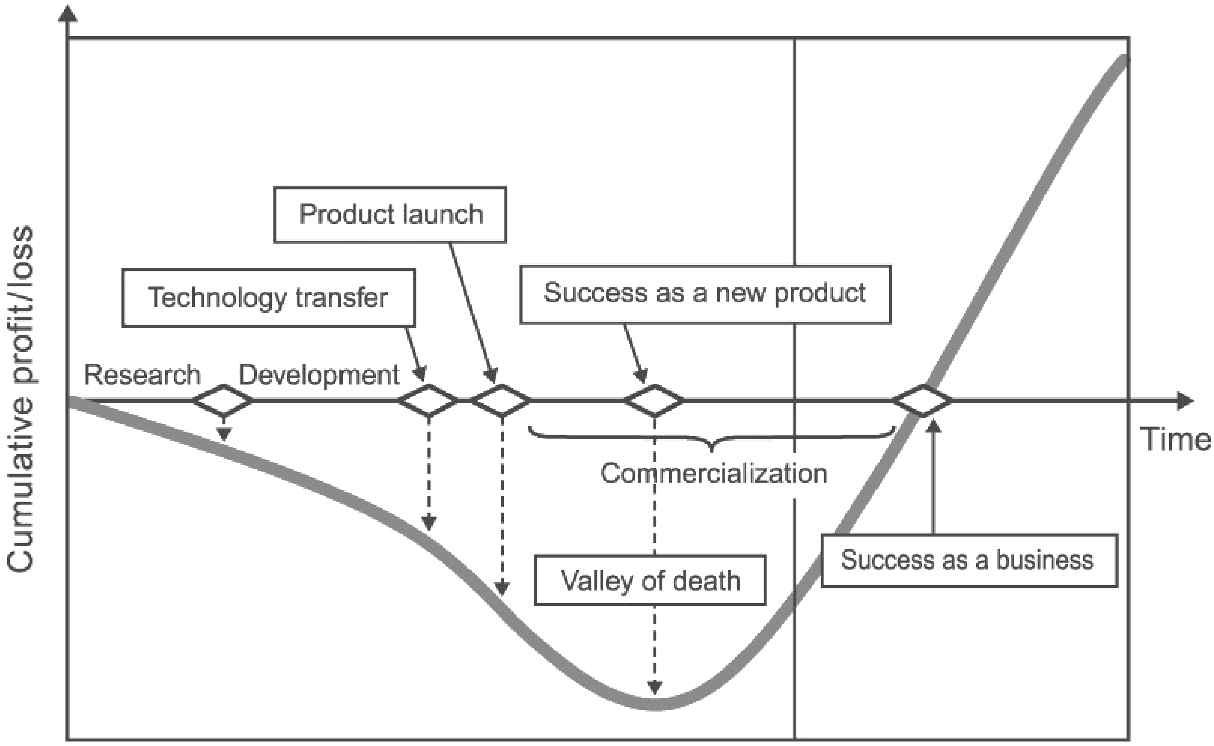

Figure 6: The Valley of Death.
Source: Blom Bank Group (2014)

2.2.3 Diffusion of Innovation

Diffusion of Innovation (DoI) offers a framework for understanding solar energy innovation distribution, and the importance of public funding for developing a service, technology, or product.

DoI explains how innovation gains momentum and spreads throughout social systems (LaMorte 2019). Understanding the DoI of solar energy innovation is essential for understanding the importance of financing for early-stage solar energy startups.

One of the main reasons why startups fail is lack of customers. DoI defines five types of customers, which are displayed in the Gaussian model (Fig. 7.):

1. Innovators –people who quickly adapt to any innovation before it is even released to the market. This segment occupies only 2.5 % of the population. This segment is also known as a segment of visionaries and technology enthusiasts.
2. The early adopter's segment takes up to 13.5 % of the population and represents opinion leaders who are usually aware of the change.
3. The early majority – is the segment that represents people who adopt innovation faster than the average person. This segment takes up to 34 % of the population.
4. The late majority's segment represents people who are skeptical about change and adapt to innovation slower. These people (34 % of the total population) adapt to innovation only once other populations try it.
5. Laggards are usually people who adapt to the innovation late or never adapts to it. Laggards occupy 16 % of the population.

(LaMorte 2019).

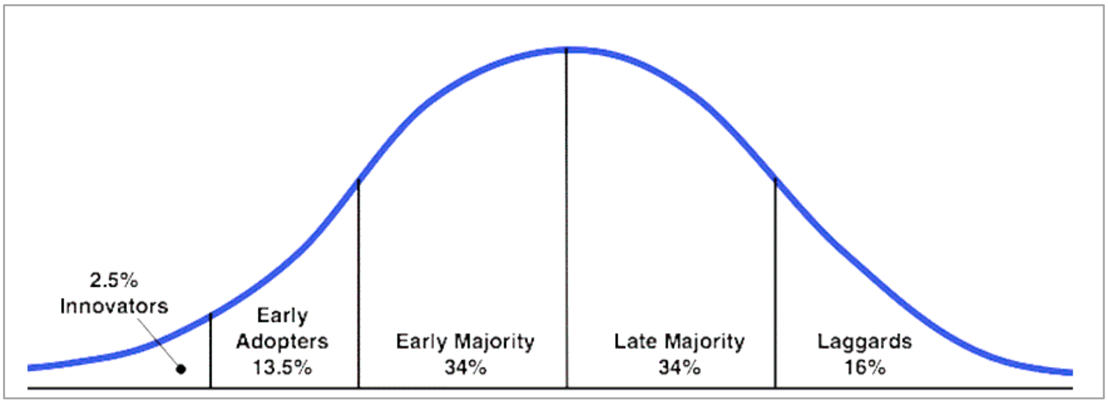

Figure 7: Theory of Innovation Diffusion.
Source: LaMorte (2019)

Between the Early Adopters and Early Majority appears the VoD. This stage is also known as “crossing the chasm” (Cho *et al.* 2008). In this stage, most startup companies fail or successfully cross the chasm with the support of external sources. This is where the government plays a huge role and supports the innovation startups until they manage to reach the Early Majority.

In this thesis, the audience segments are vital as it is related to financing opportunities. The theory of innovation diffusion goes hand in hand with analysing how startup companies managed to overcome this process and how public support can help them.

2.3 Public Support for Solar Energy Innovation

2.3.1 The Role of Government

Public funding is vital for providing early-stage support for clean energy innovation companies. Mazzucato and Siemeniuk (2017) argue that the private sector disinvests in the research stage of clean energy early-stage startups due to the short-termism of the research stage, corporate governance structure, or several macro-economic conditions such as low interest rates[5]. Usually, it takes a long time to develop a novel clean energy product, and long-term investment is essential to support this process. In this case, the public support can guarantee the finance flow through grants or subsidies (Mazzucato and Semieniuk 2017). Here, public finance plays a huge role and goes beyond the neoclassic economic approach that the government needs to solve the market failure[6]. Mazzucato and Semieniuk (2017) suggest that public finance can also shape the market by mission-orientated innovation investment. Public financing is vital for creating the markets through procurement policy and bold demand policies that allow new technologies to disperse.

2.3.2 Solar Energy and Renewable Energy in the EU

In Europe, solar energy is not a new trend. In 1991, Germany started introducing feed-in-tariff for renewables in 2000, European solar PV installations reached 20% of global solar PV installations (European Commission 2020a). In 2008, Europe dominated more than 70% of the solar PV energy market worldwide, and in 2009 the Renewable Energy Directive was introduced and created a base for renewable energy targets. From 2004 to 2018, the gross renewable consumption increased from 9.6% to 18.9% (European Commission 2020a).

In 2019, the EU's Renewable Energy Directive was revised and adopted by the Clean Energy for all Europeans' package. This package includes a renewable energy target of 32%

[5] Interest rate is the amount that a lender charges for the use of the assets used (Banton 2020).
[6] The market failure is a situation when the individual incentives for rational behaviour do not lead to rational outcomes: "insufficient distribution of goods and services in the free market" (Investopedia 2020).

and became one of the main tools to implement the EU Energy union's strategy, adopted in 2015 (European Commission 2020b). Additionally, the European Green Deal was established in 2019. The European Green Deal is a set of policies that aims to help the EU become carbon-neutral by 2050 (European Commission 2020c). The European Green Deal Investment Plan was established as a part of the European Green Deal, and aims to increase funding for the transition, creating an enabling framework for private investors and the public sector to facilitate the investments and provide support for sustainable projects (European Commission 2020d).

The EU climate strategy and targets are divided into three periods: 2020, 2030, and 2050. Target 2020 included a 20% cut in greenhouse gas emissions (from 1990 levels), 20% EU energy from renewables, 20% improvement in energy efficiency, and 21% cut of greenhouse gases from travel industry (from 2005 levels). National binding annual targets varied based on national wealth. The primary tool for decarbonization was to increase the capacity of clean energy (European Commission n.d.).

Based on European Commission (n.d.), targets for 2030 included at least 40% cuts in greenhouse gas emissions (from 1990 levels), at least 32% share for renewable energy, and at least 32.5% improvement in energy efficiency. The greenhouse reduction target is implemented through the EU emissions trading system, the Effort Sharing Regulation, land-use, land-use change, and forestry regulation (European Commission n.d.).

By 2050, the EU Commission aims to be carbon neutral with economy net-zero greenhouse gas emissions. The tools to reach this target include the Resolution on Climate Change (2019) and the European Green Deal (2020) (European Commission n.d.).

2.3.3 EU Solar Energy Support Programs

This thesis focuses on Lithuania, but the EU support for solar energy innovation needs to be discussed first because Lithuania is an EU Member State. The EU Commission defines solar energy as derived from the sun in the form of Photovoltaics (PV), concentrated solar power (CSP), and solar heating and cooling (European Commission 2020e). For solar PV, the EU aims to fund research on new materials, make solar panel design more efficient, and lower the cost of electricity generation. To support CSP development, the EU aims to fund research projects that work on identifying the more efficient cycles and components of technology. In addition, it is essential to encourage solar modules and other equipment in Europe, as manufacturing processes can be unsustainable in other countries due to the lack of environmental standards (Interviewee 4 2021).

The European Commission (2020e) predicted that 2021 is a sufficient time for solar energy innovation development because of the introduction of the European Green Deal. The European Green Deal aims to fund research and innovation in all cleantech sectors, including solar energy (Interviewee 15 2021). Key current funding opportunities available for solar energy innovation in Europe are displayed in table 1.

Table 1: EU funding programs.
Data source: European Commission (2020e)

Program	***Definition***
Horizon 2020	Horizon 2020 aims to support research projects and is one of the largest research and innovation funds in the EU with a budget of over 80 billion euros.
Connecting Europe Facility – energy	Supports energy infrastructure innovation processes.
LIFE+ Climate Action	Supports the transition to a low carbon economy and co-finances climate change mitigation and adaptation projects.
Competitiveness of Enterprises and Small and Medium-sized Enterprises (COSME)	Aims to support small and medium-size enterprises (SMEs) to access financial support in all phases of lifecycle.
Prize for renewable energy islands	Rewards local islands for renewable energy production.
Access to risk finance	Helps to gain easier access to debt and equity managed by the European Investment Bank (EIB).
NER 300 programme	Provides funding for innovation in low-carbon technology and focuses on Carbon Capture and Storage (CCS) and renewable energy technologies.
European Structural and Investment Funds	Calls for R&D&I in solar energy innovation could be found under the ESIF.
European Innovation Council (EIC) Horizon prize on Artificial Photosynthesis	Prize awarding EUR 5 million to best solution demonstrating the use of sunlight to produce a sustainable fuel ready for use in housing, transport or industry.

In addition to the EU support, Lithuania as a country also contributes to solar energy innovation development.

2.3.4 Solar Energy in Lithuania

In Lithuania, solar energy production peaked after May 12th (2011), when the Lithuanian government adopted a new law on Renewable Energy Resources. Act 2 of this law provided several incentives and measures for the development of small power plants (Parliament of Republic of Lithuania 2011). Legal regulation were favorable for solar power plants with a total installed capacity that did not exceed 30 kW (Milčiuvienė and Užkurys 2014). According to Article 49, power plants with less than 30kW generation capacity were subject to simplified permit requirements (Parliament of the Republic of Lithuania 2011). Additionally, the state pricing and the Energy Control Commission for power plants producing energy from sunlight set fixed tariffs, which in 2012 equalled to LTL 1.44 / kWh, a low tariff price which attracted entrepreneurs (Milčiuvienė and Užkurys 2014). Subsidies for solar power generation plants were promosing and atractive, and more that 15,000 applicants took interest in the project. If all applicats had been financed, the installed solar power in Lithuania could have increase from 0 MW to 1.1 MW in just half a year (Milčiuvienė ir Užkurys 2014). However, the government could not afford to finance all 15,000 applications, causing the project to fail (Milčiuvienė ir Užkurys 2014).

The failure of the government's promising solar energy investment program created a poor reputation for solar energy in the country, and solar energy innovation development slowed down due to the lack of political support (Milčiuvienė ir Užkurys 2014). However, in 2018, the reputation recovered with the development of the National Energy Independence Strategy.

In 2018, solar energy became one of the strategic energy directions based on the National Energy Independence Strategy and National Energy and Climate Action Plan of the Republic of Lithuania for 2021-2030.

Key goals reflected in these documents are:

- Competitiveness:

  Lithuania aims to well-develop the energy infrastructure, promote investments in local energy generation facilities, contribute to the effective Baltic market, develop smart remote-control systems, increase market liquidity, increase renewable energy capacity, and contribute to national climate goals (Ministry of Energy of the Republic of Lithuania 2018).

- Reliability:

  Lithuania aims to guarantee a reliable supply of energy by synchronizing countries and electricity systems with Continental Europe, completion of the Gas interconnection (GIPL), effective use of the liquefied natural gas (LNG) terminal in Klaipėda and develop cyber security capabilities in the energy sector (Ministry of Energy of the Republic of Lithuania 2018).

- Mitigation of Environmental Impact:

  Lithuania aims to mitigate the environmental impact from the energy sector through developing an energy sector free of greenhouse gasses (GHG), the expansion of solar energy, the renovation of public and apartment buildings, and the encouragement of environmentally friendly technologies and equipment (Ministry of Energy of the Republic of Lithuania 2018).

- Participation of the country's businesses in pursuance of energy progress:

  Lithuania aims to develop promising energy technologies, innovation incubators, and digital solutions in the field of energy research, cooperation among LNG terminal, business, and academia (Ministry of Energy of the Republic of Lithuania 2018).

2.3.5 Public Support for Solar Energy Innovation in Lithuania

Most of the public support for solar energy innovation in Lithuania originated from the ESIF. ESIF which includes national budgets and private co-funding are allocated by the EU for every ESIF period. As the new ESIF begins (2021-2027) Lithuania, like other EU Member States can choose how to distribute the ESIF within the country as necessary.

In 2014, Lithuania distributed ESIF based on 11 EU priorities showed in table 2.

Table 2: ESIF priorities.
Data Source: European Commission (n.d.a)

ESIF Priorities for 2014-2020
1. Strengthening research, technological development and innovation
2. Enhancing access to, and use and quality of, information and communication technologies
3. Enhancing the competitiveness of small and medium-sized enterprises (SMEs)
4. Supporting the shift towards a low-carbon economy
5. Promoting climate change adaptation, risk prevention and management
6. Preserving and protecting the environment and promoting resource efficiency
7. Promoting sustainable transport and improving network infrastructures
8. Promoting sustainable and quality employment and supporting labor mobility
9. Promoting social inclusion, combating poverty and any discrimination
10. Investing in education, training and lifelong learning
11. Improving the efficiency of public administration

There is no priority dedicated to solar energy innovation but Priority 1 and Priority 3 support small and medium-sized enterprises (SMEs) and innovation development. Priority 1, had 2 investment priorities:

> Improving research and innovation (STI) infrastructure, strengthening R&D capacity and promoting centres of excellence, especially of European interest and promoting business investment in innovation, developing links and synergies between enterprises, R&D centres and the higher education sector, in particular by encouraging investment in product and service development, technology, innovation in social and public services;…the promotion of demand, networking, clusters and open innovation through a smart specialization strategy, supporting technological and applied research, pilot lines, pre-product validation actions and advanced production capacity for KETs, dissemination of primary production and general-purpose technologies (Ministry of Finance of the Republic of Lithuania 2019,11).

The investment priorities of Priority 3 include “Encouraging entrepreneurship, by facilitating the transfer of new ideas to economic activities, and the creation of new businesses, including business incubators”, “Development and implementation of new business models for small and medium-sized enterprises (SMEs), in particular, internationalization”, and

“Supporting the capacity of SMEs to participate in growth and innovation” (European Commission 2014). Lithuanian National Authorities are responsible for distribution of the ESIF in Lithuania as is shown in Fig. 8.

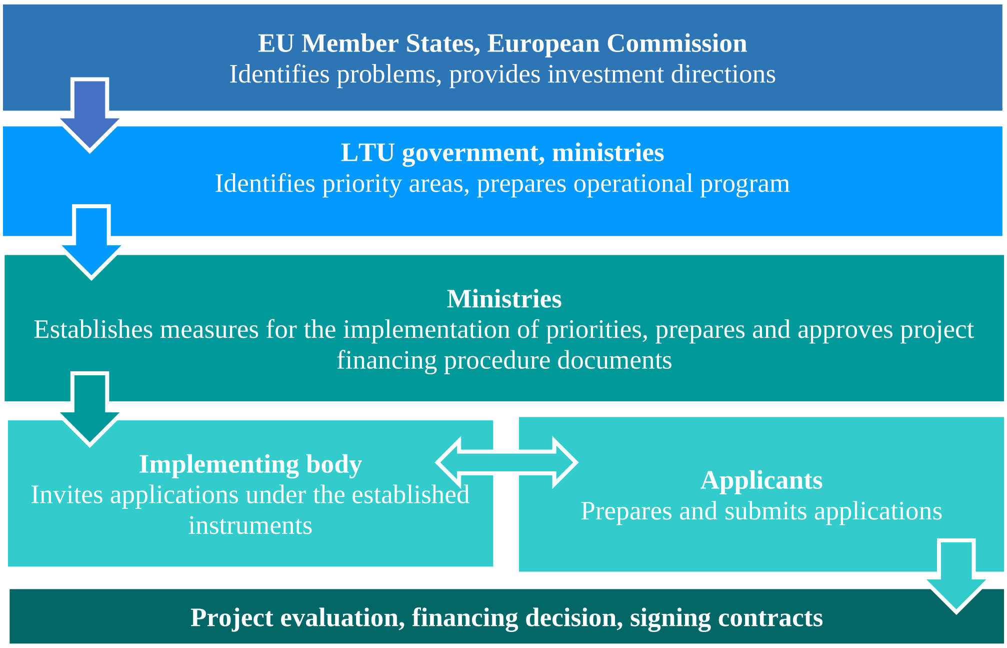

Figure 8: ESIF distribution in Lithuania.
Data source: ES Investicijos (2014a)

In addition to financial support, other support also exists and consists of a recently founded pre-acceleration program, free consultations offered by Agency for Science, Innovation and Technology (MITA), and science parks‘ services. The gaps and oportunities of both support types are accessed further in Chapters 6 and 7.

2.4 Improving Public Solar Energy Innovation Support Based on the Theory of Change

In this thesis the Theory of Change will be used to analyse the needs of startups, draw lessons from the previous ESIF period (2014-2020), and provide recommendations for the distribution of ESIF to early-stage solar energy startups for the following ESIF period in 2021-2027. Additionally, the theory of change will be used to analyse other forms of support for early-stage solar energy startups and how this support can be improved.

The Theory of Change defines a pathway through which a specific goal can be achieved. This theory includes the expected results, activities to reach the result, and how the dedicated activities lead to the result (UNDG 2021). The theory of change assists in evaluating mission-oriented processes and helps to better understand "what is being implemented and why" (Reinholz and Andrews 2020). The key principles of development from the theory of change are consultation with the stakeholders, making assumptions about how the theory will work, and identifying actors who will assist in achieving the desired results (UNDG 2021).

2.5 Summary of Literature Review

Solar energy is one of the main strategic directions of renewable energy, and Lithuania aims to reach the 2030 and 2050 goals by implementing a National Energy Independence Strategy. Two kinds of public solar energy innovation support exist in Lithuania (financial and other support). Other support includes acceleration programs, consultations, and science parks' services. Most of the financial support comes from the ESIF and is allocated based on 11 priorities, and Lithuania is responsible of its distribution. Solar energy innovation in Lithuania falls under two ESIF priorities: Priority 1 and Priority 3. The government's role in promoting solar energy support in Lithuania is creating a strategy and encouraging legal environment. Financing early-stage startup innovation companies is essential for developing an innovative idea and reaching the commercialization phase (overcoming VoD). Investing in solar energy startups is risky, which is why VC and PE usually avoid investing in them. However, public support is critical because it can help startups sustain while developing their products and looking for customers or PE and/or VC investors. The European Union supports solar energy innovation through various programs, but the main programs are Horizon 2020 and ESIF. However, it is still unclear how this support effects early-stage solar energy startups and if this kind of support is effective. This thesis aims to address this knowledge gap by understanding the needs of early-stage solar energy startups and analysing the lessons learned from the previous public support period in 2014-2020. This will be implemented to make timely recommendations for the next public support period and maximize the effectiveness of early-stage solar energy startup support in Lithuania from 2021-2027.

3. Methods, Analytical Framework and Limitations

This section presents the analytical framework and methods used for research: tracking the finance flow for solar energy early-stage startups based in Lithuania, secondary analysis, semi-structured interviews, and the pilot project.

3.1 Analytical Framework

In this thesis, the theory of change was used to draw policy recommendations for the support of solar energy early-stage startups in Lithuania (Fig.9).

To provide these recommendations and reveal the desired outcomes for improving support for early-stage solar energy startups in Lithuania, the needs of these startups were analysed, and lessons were drawn from the previous ESIF funding period.

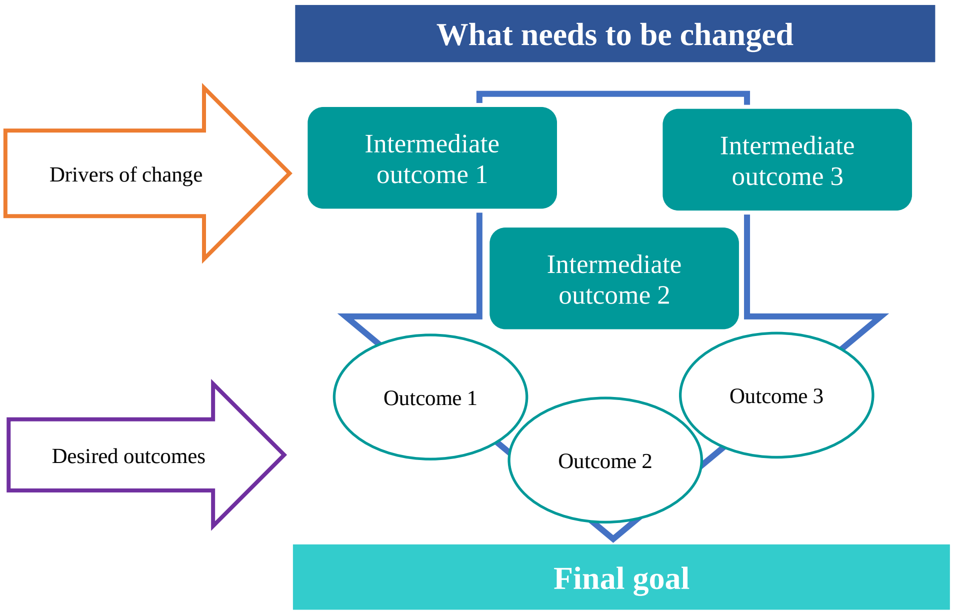

Figure 9: Thesis analytical framework based on theory of change.
Source: Author according to guidelines of (NPC 2014)

3.2 Tracking ESIF Financial Flow into Solar Energy Startups in Lithuania

Based on Novikova *et al.* (2019), financial flow tracking diagrams can help design efficient policy instruments. The diagram illustrates the amount of the public funding that is distributed specifically to solar energy innovation startup companies. The diagram is divided into four dimensions: source of investment, priorities, financial instruments, and users. The diagram does not present the intermediaries because the same intermediary (Lithuanian Business Support Agency) was applicable for all instruments as well as the type of financing (grants). In addition, the project developer was the same as the final user. For this reason, project developer dimension is not included into the diagram. The source of investment arises from the national or EU funding supervised by intermediaries (in this context - governmental actors). Early-stage solar energy startups were financed by providing grants. The investments were tracked from 2014 to 2020 because this period is the EU Cohesion Policy and ESIF programming framework (7 years).

As EU Structural Investment Funds are the primary public investment sources, the finance data was drawn from the publicly available national reporting system *Esinvesticijos.lt.* This portal presents all public financing data. The instruments' financing data provides the project's value, expenses paid by the company itself, expenses covered, and disbursed funding. The criterion for final users included: the startup is providing systemic innovation, is founded from 2016 to 2020, and operates in the solar energy industry.

In this thesis, public finance of solar energy innovation refers to funding by the EU, or national fund disbursement for solar energy startup development. The diagram presented later in this thesis (see Chapter 7) displays the amount disbursed to solar energy startups in Lithuania from 2014-2020. The tracking of ESIF disbursement for solar energy innovation is based on the national climate finance tracking used by Hainaut *et al*. (2017).

Only the disbursed funding amount is assessed in the finance flow diagram, as it represents real conditions.

3.3 Secondary Analysis

Secondary analysis is a common method used to verify the findings (Heaton 2019). In this thesis, secondary analysis was used to implement interview analysis and answer all the research questions. Data used includes ESIF evaluation documents, the EU and Lithuania's Operational program, articles by the government of Lithuania, the Esinvesticijos.lt website where all the information about EU investments is reported, instruments funding orders by the state of Lithuania, articles founded on solar energy startup development in Lithuania, EU Commission statements, IRENA's and IEA statements.

3.4 Qualitative Expert Interviews

The main goal of expert interviews is to gain insight on the research topic (Kolb 2008). Interviews were essential in understanding the role of public finance in boosting solar energy innovation in Lithuania, to draw the lessons and learn how public finance of solar energy innovation can be improved. Expert interviews became a central object of the empirical research in a few decades (Flick 2018). Expert interviews were chosen because specific knowledge from different ecosystem actors was necessary to understand what the role of public support is, what the needs and gaps of public support are, and what can be improved.

Interviewees were selected based on the solar energy startup ecosystem explained in the literature review (see Chapter 2) and recommendations from the key actors. Interviewees were all experts on renewable energy or solar energy innovation working in the field for more than 5 years. Selected interviewers helped understand the main challenges of public financing of solar energy startup companies in the R&D&I stage. Experts were divided into five different groups:

1. EU solar energy innovation financing experts – these experts provided an overview of the need for solar energy innovation in the EU, shared their expertise on the financing of solar energy innovation startup companies, and provided recommendations for Lithuania's public sector. These experts were selected based on their specialisation in solar energy innovation financing.

2. Lithuania's solar energy innovation public financing experts – these experts reflected on the current and past solar energy innovation public support in Lithuania, and drew lessons from the 2014-2020 solar energy innovation startups financing period in Lithuania. These experts were selected based on the main actors in the ecosystem.
3. Lithuania's solar energy innovation private financing experts – these exerpts shared the public sector's recommendations on how solar energy innovation support can be improved. These experts were selected based on their duration of working in the field and specialisation in solar energy innovation financing.
4. Solar energy innovation startup founders from Lithuania – these experts shared their experience from creating solar energy innovation startups in Lithuania and provided financing recommendations to the public. To understand the broader view, this group presents startup founders from sucessful early-stage startups, emerging early-stage stratups, and startups that are struggling.
5. Other experts working in academia provided the academic view on solar energy innovation financing in Lithuania.

All 17 experts were interviewed based on the order presented in the Annex 1. The organisation of new interviews was halted after experts started to reveal similar information and no new insights were gained. The list of interviewed experts including position, title, and organisation, is presented in Annex 1.

3.4.1 Conducting Interviews

The interviews were semi-structured interviews which allowed a good balance between the structured questions and the interviewees willingness to expand the discussion topic (Given 2008). Thirteen of seventeen interviews were conducted on teleconference in March and April 2021. Each interview lasted from 30 to 60 minutes, depending on the availability of the interviewees. Four out of seventeen interviews were received as answers to emails. To start, introductory emails were sent to each interviewee introducing the thesis project. Once confirmation was received, an online meeting was scheduled on the MS Teams or an email with questions was sent. Consent to participate in the study and be recorded was gained from all participants at the start of the interview.

Interview duration:

First, each group of interviewees was asked broad questions about the definition of solar energy innovation. Further questions were divided into three categories:

1. The government's role in helping solar energy innovation startup companies overcome the VoD.
2. What are the lessons learned from solar energy innovation financing for startup companies in 2014-2020.
3. What and how can public support of solar energy early-stage startup companies be improved.

The full list of questions can be found in Annex 2. The follow up questions were asked according to the interviewees answers to the prepared questions.

3.4.2 Information Analysis

The recorded interviews were analysed manually using an inductive coding approach. The analytical strategy used, was multiple readings of the raw data and its interpretation. The findings were raised directly from the analysis of raw data and not from expectations (Thomas 2006). The raw data was then summarised, and the links between the research objectives and the raw data were found. All codes had the same importance (flat coding approach) and in vivo coding was implemented because the aim of the analysis was to stay as close as possible to the interviewees phrasing which would allow the capture of key elements of what has been described (Given 2008a). Themes, categories, and codes are presented in table 3.

Table 3: Themes, categories, and codes used to analyse semi-structured interviews.
Source: Author

RQ	Theme	Category	Code
1	Needs of start-ups	Business knowledge	Lack of business knowledge
		Mentorship	Reduced risk, easier to overcome VoD, increased network
		Pre-seed funding	Keeping team motivated, developing a prototype, public finance application process, overcoming VoD
1	Role of public support	Ecosystem development	Legal, strategy formation.
		Funding	ESIF
		Other support	Pre-acceleration, consultations
2	Lessons learned	Lack of investments	Investing to innovation, investing to solar energy innovation
		Lack of networking	International cooperation, cooperation among start-ups
		Political stability	Strategy, ecosystem formation
3	Improving future support	Long-term strategy	Promotion, clarification
		Ecosystem	Human resources, communications, legal environment

3.5 The Pilot Project

Case studies are highly recognised in social science, as they can provide in-depth explanations to phenomena (Zainal 2007). The case study in this thesis is a pilot project. It has three goals: to understand the needs of one solar energy early-stage startup, to recognize the support opportunities and gaps, and learn how the suggested public support improvements could help early-stage innovators to develop. *Airion* was created as a pilot project for this research. A working prototype is being developed, and the basic monetization models have been defined. Currently, *Airion* is an early-stage innovator that is developing a prototype, participating in hackathons, and looking for public support opportunities in the solar energy innovation field. The pilot project analyses the needs of *Airion* in comparison to existing support opportunities.

3.6 Research Challenges and Limitations

In general, the main challenge of this research was the need to narrow down the topic. The original idea was to analyse the public support for cleantech startups in three Baltic states (Lithuania, Latvia, Estonia). However, after researching the topic, it seemed that three months will not be enough time to focus on cleantech startup support in the Baltics, and it was therefore decided to focus only on solar energy early-stage startups in Lithuania, due to the accessibility and a sufficient number of startups.

A fundamental limitation observed throughout the secondary analysis was that information dedicated to solar energy innovation was limited. The information accessed includes analysing energy innovation, clean energy innovation, and innovation finance in general. However, in Lithuania, solar energy innovation support mechanisms are the same as other innovation mechanisms. For this reason, the information on clean energy innovation was assessed and applied to solar energy.

The main limitation of the interview stage was that it was complicated to reach the interviewees. For example, there is one more startup company in Lithuania that could provide insights, but no reply was received. A similar situation occurred with interviewees from the private investors group. In the end, all necessary approaches were collected.

A challenge related to interviews was that the Ministry of Finance and Ministry of Economy and Innovation were hesitant to answer any questions dedicated to public support experts in Lithuania, each claiming that the other ministry should answer these questions. This issue was solved by contacting the exact people from each ministry who later answered the questions, but this process was time consuming.

In terms of the finance flow diagram, an original plan was to track total investments, including private and public investments. There was no information found about private investments. For this reason, only public finance and private co-funding investments in solar energy innovation startups were tracked in the finance flow Sankey diagram.

For the pilot project, time constraint was a vital issue. It was essential to create the first part of the prototype to understand the resources needed and understand the monetization model that can be applied. This was important for analysing the needs of the pilot project. The analysis suggested that in order to create a full working prototype, additional funding is needed, and that became a part of the analysis.

4. The Pilot Project: an Environmental Monitoring Network for PV Solar Power Plants

The Airion project is an environmental condition measuring network and action platform, that helps increase the efficiency of solar power plant maintenance. *Airion* consists of two key elements: a weather station network (Internet of Things (IoT))[7] and a user-friendly platform. The weather station (Fig. 10 (left)) measures the environmental conditions, including temperature, wind speed and direction, and precipitation, and sends this information to the cloud-based platform (Fig. 10 (right)). Received data is analyzed and sent to the end-user as an action notification. Currently, the public environmental monitoring network of Integrated Pest Management Information, Consultation and Training Information System (IKMIS) exist. However, IKMIS is more focused to agriculture and cannot provide precise field data due to the limited coverage (IKMIS n.d.).

Figure 10: *Airion* project prototype. On the left – weather station and platform on the right.
Source: Author

[7] Internet of things (IoT) – defines the number of electronics that are connected to the internet to send the data or receive the instructions (Fruhlinger 2020).

The blue arrow in Fig. 11 illustrates that *Airion* is under the development stage and is approaching the technology transfer stage (which means moving closer towards the VoD). As discussed in Chapter 2, the support for *Airion* is particularly important due to the lack of resources to develop a full prototype and a high risk of failure.

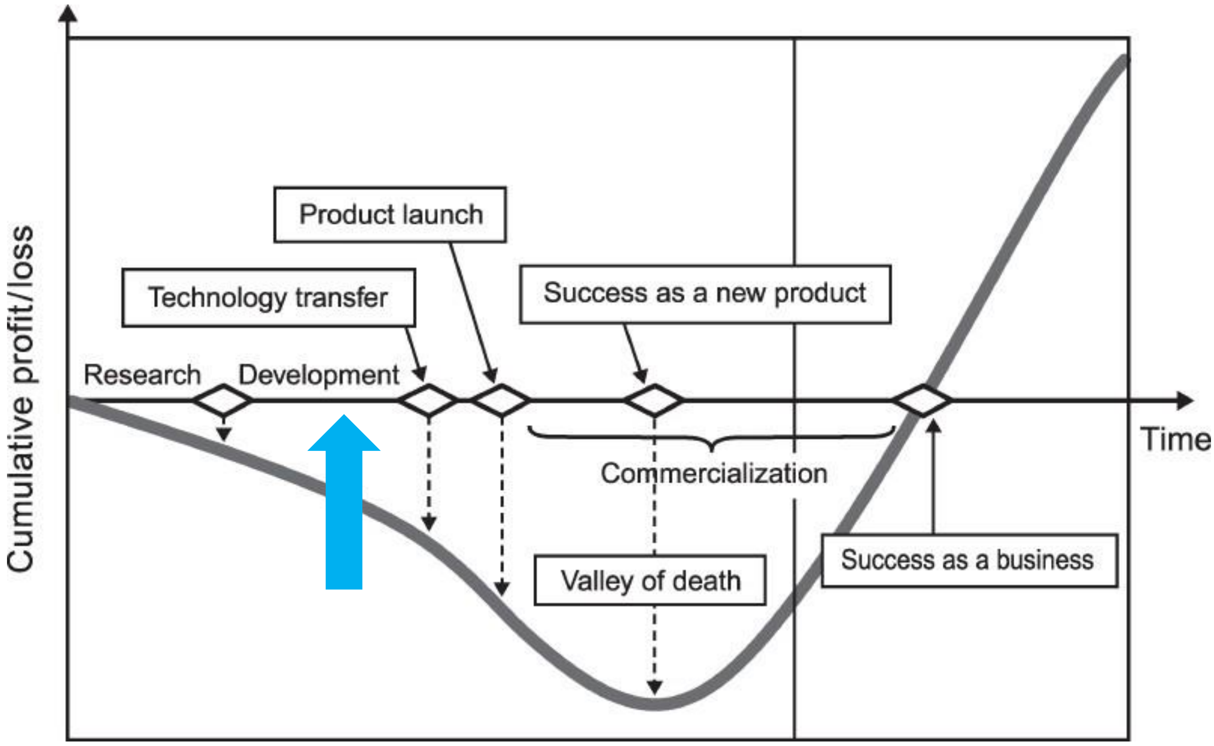

Figure 11: *Airion's* project development stage.
Source: Blom Bank Group (2014) with amendments

To avoid VoD, the *Airion* team needs to sustain the product development until the product reaches commercialization. To do that, *Airion* needs to secure investments. Due to the lack of support from the private sector, public support opportunities need to be found. To identify the best support suited for *Airion*, the needs of solar energy startups and support gaps and opportunities in Lithuania, as well as lessons learned, and possible improvements of support mechanisms are analysed in further chapters.

5. The Needs of Solar Energy Early-stage Startups in Lithuania for Overcoming the VoD

5.1 A Need for Pre-seed Funding

Almost every kind of product development requires pre-seed funding[8]. Pre-seed funding is essential for solar energy early-stage startups because it helps develop a working prototype or Minimum viable product (MVP)[9] which are needed to attract investors and potential clients (Audretsch *et al.* 2012). Attracting potential clients or investors for an early-stage startup usually reduces the risk of falling into the valley of death (VoD) and speeds up the diffusion of innovation (DoI), discussed in the literature review.

For *Airion*, one part of the working prototype was developed using private funding – the weather station prototype. However, half of the prototype does not present the functionality and does not help attract investments. For this reason, the second half of the prototype needs to be developed – an interactive platform. As it is shown in table 4, the estimated time needed to develop a full working prototype for *Airion* is around six months, and the funds needed are EUR 94,906 based on Lithuania's market prices (table 5).

Table 4: Timeline.
Source: Author

Milestone	*June*	*July*	*August*	*September*	*October*	*November*
Improve a weather station design						
Print 50 weather stations						
Develop network						
Collect and storing data						
Build algorithms to analyse data						
Create user friendly platform						
Deployment						

[8] Pre-seed funding – a type of funding that is designed to help a stratup with its initial formation and beginning of operations (ULP University 2020).
[9] Minimum viable product is a product that allow the team to collect the maximum amount of validated learning with the least amount of resources (Ries 2009).

A significant amount of the pre-seed funding needs to be dedicated to hiring and maintaining product developers (EUR 81,000). The team of developers is recognized as an essential part of the team because of their work on prototype building, which is essential for attracting investments (LRT.lt 2019).

Table 5: Resources needed to build a prototype of *Airion.*
Source: Author

Resource	***Quantity***	***Capital needed for half a year in EUR based on market prices in Lithuania***
Product development team		
Backend developer	2	18,000
Product owner	1	9,000
Frontend developer	2	18,000
UX designer	1	9,000
Quality assurance engineer	1	9,000
CTO	1	9,000
CEO	1	9,000
Marketing and sales		
Sales manager	1	9,000
Marketing manager	1	9,000
Meetings and client outreach		5,000
Tools and space		
Office rent	1	6,600
3 D printer	1	1,000
Working places	9	27,000
Cloud fee	1	1,000
Other		
Internet	1	200
PV solar power plant	1	3,600
Legal costs	1	4,000

In Lithuania, most early-stage startups have limited available funds to hire a team, and not paying for project development decreases the team's motivation to work on the product (Bolt 2021). Paying a team is essential to keep the team focused on and dedicated to a product because otherwise team members need to find additional income sources, and their focus becomes scattered (Interviewee 6 2021). In addition to the team, product development costs include materials needed to create a prototype. In *Airion's* case, the required equipment is a 3D printer, polylactic acid filaments, sensors, a 3D printing modeling tool (AutoCAD), cloud-based servers, and computers to develop a product. For developing an interactive platform, developers need to have desks that include computers, monitors, and other office gear (EUR 12,000). To save funds, the current team uses personal computers. However, personal gear wears out and needs a replacement (Interviewee 6 2021). Without primary funding and guaranteeing future expenses, developing and testing a primary product while simultaneously developing a business is problematic (Interviewee 1 2021, Interviewee 6 2021).

Pre-seed funding is also essential for reaching the first clients and introducing a prototype. It is important because a client who is willing to pay for future solution provides funding to current product development and highlights gaps that can be improved (Kilinc *et al.* 2015). The primary method for reaching clients – which was observed for solar energy startups in Lithuania – is through marketing campaigns (MITA 2021). Lithuania's average marketing campaign price is from EUR 1600 to EUR 2900 a month (Marketingo valdymas n.d.). For *Airion*, allocating such an amount every month is complicated because the company is under the break-even point[10].

In addition to the marketing campaign, the funds for sales need to be allocated, including transportation costs, product representation cost, and communication costs (Interviewee 6 2021). It is important to highlight that these investments do not always pay off because of the client's choice to invest in the product or not (Interviewee 6 2021).

Another critical aspect of product development and the need for pre-seed funding is certification. Electronics in the EU need to have a CE marking[11] (Your Europe 2021) and certification prices depend on the technology used in the product development process. For *Airion*, certification is unnecessary because the main product is built from already certified

[10] Break-even point – means that there were no net profits or no net losses for the company – it "broke even" (CFI 2021).

[11] CE marking – indicates that a product meets EU safety, health and environmental protection requirements (Your Europe 2021).

materials, and *Airion* can test its products under the regulatory sandbox[12] legal product testing state in Lithuania. However, certification products might be necessary for other solar energy innovation products that involve electronics. For example, to sell PV solar technologies in most of the EU countries, the products need to meet standards such as the IEC61215 "Crystalline silicon terrestrial photovoltaic (PV) Modules – Design qualification and type approval, IEC61646 Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval, D1.2: regulatory Framework 17 Grant Agreement 691768, and IEC 61730/EN 61730 Photovoltaic (PV) module safety qualification." (European Commission 2016,17). Certification prices (which can be as high as EUR 50,000) are often a barrier for reaching foreign markets, and early-stage startup companies in Lithuania usually do not have such funds (Interviewee 5 2020).

Pre-seed funding is also needed for meeting eligibility criteria in applying for public grants. As mentioned above, public support is vital for early-stage solar energy startups in Lithuania because private investors are unwilling to invest due to the high risk (LRT.lt 2020). Most of the public financial support in Lithuania originates from ESIF (Interviewee 10 2021), but early-stage startups without pre-seed funding do not meet the requirements for funding instruments. Funding instruments are local ESIF programs under which projects are funded. The ESIF 2014-2020 programming period instruments that could provide support for *Airion* were "Inostartas" (Eng. "Inostartas"), "Intelektas. Bendri Mokslo ir verslo projektai, Inočekiai" (Eng. "Intelligence. Joint science and business projects"), and "Ekspermentas" (Eng. "Experiment"). The main goal of "Inostartas" instrument was "to encourage the creation and development of new innovative SME entities, ensuring the development of innovative ideas, products, and services, to promote the independence of companies in carrying out R&D work

[12] Regulatory sandbox allows innovators to test new products and services in a real-world environment without applying regular rules (Ofgem 2018).

within the company" (MITA 2021a). However, the application criteria claim that "The applicant's annual turnover in the last financial year before the submission of the application is at least EUR 15,000…the financial statements for the last year before the submission of the application will be evaluated." (Minister of Economy and Innovation of the Republic of Lithuania 2018, Chapter III, 17.3). This suggests that *Airion* is not applicable for "Inostratas" because *Airion* is under the break-even point and cannot prove its financial turnover. There was a similar situation with the "Inočekiai" instrument (Eng. "Inocheki"). "Inočekiai" is dedicated to small and medium-sized enterprises (SMEs) starting to or carrying out innovative activities, excluding public institutions. These enterprises can receive a fixed amount of targeted financial support to purchase services from research and study institutions. The main feature of this instrument is "fast money for business," i.e., rapid support for research and development. However, *Airion* is not eligible for this instrument because its yearly turnover does not reach EUR 10,000 (ES Paramos 2021).

On the other hand, *Airion* met the criteria of the instrument "Intelektas. Bendri mosklo ir verslo projektai" as well as "Ekspermentas". These instruments aimed to encourage companies to invest in research and experimental development to develop innovative products, services, or processes and promote the development of companies by investing in the creation and development of research, development, and innovation (R&D&I) infrastructure. Based on the requirements described for priority 1 ("promotion of research, experimental development and innovation") of the investment operational program of the European Union funds 2014–2020 description of project financing conditions, *Airion* would be able to apply for this instrument and receive financial compensations for product prototype development (Ministry of Finance of the Republic of Lithuania 2019,27). However, for "Ekspermentas", and "Intelektas. Bendri mokslo ir verslo projektai" administration costs are EUR 12,584 (Ministry of Finance of the Republic of Lithuania 2019). *Airion* cannot pay such an amount because it does not have pre-seed funding. Early-stage startup companies usually cannot prove the eligibility for public support because they are under break-even point or do not own assets.

Interviewee 1, 6, 5 and 3 (2021) agreed that the requirements for each public finance support instrument differ, but project developer's eligibility requirements and administration costs are too high for early-stage startups companies. Interviewee 1 (2021) adds that his product development stumbled when he could not prove more than EUR 50,000 of owned assets to receive governmental support. Interviewee 3 (2021) highlights that:

> The only asset that early-stage startups usually have are laptops, tables, and chairs. They do not have cars, real estate, or something similar. For this reason, it is complicated to prove assets to be eligible for public grants.

5.2 A Need for Mentorship

Besides pre-seed funding, early-stage startups often need guidance or advice on business-related matters to overcome the VoD.

For *the Airion* team, a mentor could provide a different opinion on challenges faced during project development and help gain valuable connections. According to Kuratko *et al.* (2021), mentors reduce the risk of failure and are essential for helping to kick off an idea or overcome business-development-related struggles. *Airion's* current team is technology and science-oriented and has limited experience and knowledge about business management, legal requirements, customers, and competitors, which are essential for introducing their product in Lithuania's energy sector (Energypreaccelerator.lt 2020).

Commonly, early-stage startup founders in Lithuania need guidance in introducing the idea to the market and lack leadership and decision-making experience. The primary mission of mentoring is to share experiences (VCA LT n.d.). Consulting with mentors about business development can help to increase the possibility of attracting investments by approximately 70% (Dževerskytė 2020). Besides, interviewee 14 (2021) adds that mentorships assist in developing new partnerships:

> Mentorship can help to gain new partnerships which can help to ensure the appeal to target markets and integrate the product to the value chains as well as be useful for a specific application.

5.3 A Need for Collaboration

Collaboration for startup companies can help in present activities and positively influence future development (Kelly *et al*. 2002). Partnerships and collaborations were observed as main elements that can help early-stage startups speed up the diffusion of innovation (DoI) towards acceptance in the audience. In addition, collaborations and partnerships can help to overcome the VoD. Commonly, startups lack the bases of influence and endorsement, and stable relationships with important external actors and partnerships with government, corporations, or other startups that can help strengthen their network and gain pre-seed funding (Baum *et al*. 2000). For *Airion*, the best partnership with the government or a corporation could be a public-private partnership (PPP), because they help to gain the financing for full product development as well as help to understand the needs of customers.

Besides the benefit for *Airon*, partnerships and collaborations are mutually beneficial. For example, *Airion's* collaboration with the government would bring better data precision to the already existing public network (IKMIS). Private-public partnerships allow both sectors to use their strengths to achieve the best outcomes:

> While the public sector has regulatory power and access to cheap capital, it is relatively slow and unable to understand innovation's granular details, and the private sector has the opposite strengths and weaknesses (Interviewee 14 2021).

On the other hand, interviewee 16 (2021) argues that the public-private partnerships model is more suitable for startups that already provide a working solution.

In addition to partnerships with government or larger corporations, collaboration with other startups is vital for *Airion* as it would help reduce the costs of testing. Currently, to test a product, *Airion* needs to build a PV solar power plant. Based on Lithuania's market prices, building a PV solar power plant costs EUR 3,489 per 3 kW and EUR 2,520 with governmental support (Energija Man 2020). Partnership with a company that already has Solar PV could reduce *Airion's* product testing expenses. In addition to reduced expenses, partnerships among startups can help solve challenges faster, encourage communication and strengthen the solar energy startups ecosystem (Interviewee 6 2021).

6. The Role of Public Financing and Support Opportunities for Early-stage Solar Energy Startups in Lithuania

6.1 The Government's role in Supporting Early-stage Solar Energy Startups in Lithuania

Government support for solar energy innovation in Lithuania started to grow along with the beginning of the previous ESIF programming period (2014-2020) and global solar energy innovation trends. The strategy and ecosystem needed to be strengthened before solar energy solutions could be implemented. Based on Malysis and Juozapaitienė (2020), the role of the Lithuanian government was to provide consensus on the strategic level goals and the means to achieve them, to allocate public resources efficiently, to provide political support integration into international innovation ecosystems, develop an innovation-friendly regulatory environment, and promote innovative solutions in financial risks conditions. Currently, the role of the government in supporting early-stage solar energy startups includes the development of a legal environment, providing funding, and forming a long-term strategy.

The government plays a vital role in developing laws and regulations that encourage innovation. Recently the government legitimized the concept of a regulatory sandbox, which reduced legal burdens for new product testing. Before 2019, an innovator willing to test a pilot energy product or service had to obtain permits in the same way as a regulated company, which was time-consuming and labor-intensive, and sometimes it was impossible to test the innovation in real conditions (TeisePro 2019, Interviewee 8 2021). Interviewee 4 (2021) adds that legal changes encouraged startup development in recent years:

> These changes in the legal environment reinforced the development of startups that operate in clean energy and all startups whose final product can improve the performance, technology, implementation, or maintenance of clean energy products, including solar power generation.

The government also plays a decisive role in solar energy innovation strategy formation. In the past, solar energy innovation support in Lithuania highly depended on political interests.

Before 2018, there was no long-term strategy for solar energy development. This brought uncertainty and discouraged the innovation processes (Interviewee 5 2021). In 2018, the National Energy Independence Strategy was set, and Actions Plan for Strengthening Energy Innovation Ecosystem was introduced in 2020. Clean and solar energy and innovation became one of the leading renewable energy strategic directions (Interviewee 4 2021). This plan set out more than 50 measures to develop and strengthen the energy innovation ecosystem in infrastructure, human resources, products and services, the regulatory environment, science, and technology (Ministry of Energy of the Republic of Lithuania 2019a). Most of these measures were planned to be implemented in 2020-2023 (Ministry of Energy of the Republic of Lithuania 2020a).

6.2 The Importance of Public Support in Encouraging Early-stage Solar Energy Startups in Lithuania

The government plays a vital role in supporting early-stage solar energy startups financialy and providing other forms of support. In Lithuania, private investors tend to invest in mature startups and not in early-stage startup companies (LRT.lt 2020, Interviewee 5 2021). Most early-stage solar energy R&D&I startups in Lithuania struggle to gain pre-seed funding and partnerships for their ideas, therefore, public support plays an essential role, as it can help the company sustain itself until it reaches commercialization (Interviewee 14 2021). For *Airion*, public support is vital to build a complete prototype and test it in the market. Testing in the market needs to take place as soon as possible while the market niche is still open (Interviewee 10 2021). It is essential to highlight that public finance is more important for solar energy startups than for any other startups because the lifetime of the solar energy industry products is short. For example, PV panels require approximately 20 years of guarantee to be sold in the market. If they deteriorate earlier, compensation needs to be provided. In this case, public funding helps compensate for expenses or find new early-stage investors (Interviewee 9 2021).

6.3 Gaps and Opportunities of Existing Public Support for Solar Energy Early-stage Startups in Lithuania

The gaps and opportunities for public financial support will be discussed in Chapter 7. This chapter discusses gaps and opportunities in additional support systems for solar energy startups, that are not financial.

Other support systems for early-stage solar energy startups in Lithuania include the Agency for Science, Innovation and Technology (MITA) consultations, the services of science parks, energy pre-accelerator, and TechHub (MITA 2020). Of these support measures, *Airion* managed to use the energy pre-accelerator and plans to use TechHub in the future. Other support opportunities were not suitable due to their price or long waiting time. The following section explains these support systems in detail.

6.3.1 The Energy Pre-accelerator

A form of public support which *Airion* was able to utilize is the energy pre-accelerator, developed by the Ministry of Energy in 2020 (Ministry of Energy of the Republic of Lithuania 2020b). The energy pre-accelerator is designed to nurture innovations in solar energy, biomass, geothermal energy, hydrogen, batteries, liquefied natural gas, cybersecurity, e-mobility and other areas, to help a business grow faster and more easily. The *Airion* team participated in the pre-accelerator and gained valuable insights about the existing ecosystem.

6.3.2 TechHub

TechHub is a pre-accelerator program dedicated to early-stage startups (MITA 2021c). TechHub aims to create conditions for the integrated development of early-stage innovative business ideas, encourage an intensive growth of startups. Based on Interviewee 8 (2021) TechHub is a crucial tool to refine an idea and develop a business model. TechHub is divided into six cycles, while each cycle lasts for three months. The pre-accelerator provides professional, international-level consulting, mentoring, and business development support services to early-stage innovative startup teams that generate business ideas. *Airion* did not register for the current cycle of pre-accelerator due to participation in the international acceleration program. However, the *Airion* team considers joining TechHub in future cycles.

6.3.3 MITA Consultations

MITA consultations provide information about applying to national and international support programs, tax breaks for startups, idea development, and commercialization (MITA 2021b). Additionally, MITA consultations provide essential information about funding opportunities and business model development. Consultations are free and involve advising on business strategy modeling, strategy, preparation for applications for the ESIF instruments, and project administration (MITA 2021b). However, registration for the consultation process can be slow. The *Airion* team had registered for a consultation but did not receive a reply.

6.3.4 Science Park Services

Science parks' services, another form of support that *Airion* did not access, provide expert advice in developing prototypes, market research, incubation and acceleration, legal consultations, search for partnerships, and office spaces (MITA 2020). In Lithuania, science parks focus on mature startups. Science parks offer price reduction of legal services, insurance, accounting, banking, office supplies, or translation, but it is still too expensive for early-stage startups. In Lithuania, there are ten science and innovation parks: Northtown Technology Park, Klaipėda Science and Technology Park, Kaunas Science and Technology Park, Visoriai Information Technologies Park, Sunrise Valley Science & Technology Park, Panevėžys Science and Technology Park, and Science and Technology Park of Institute of Physics. These parks are more dedicated to mature startups because their rental and consultation services are high (Interviewee 6 2021).

7. Financial Support and Funding Distribution

7.1 Allocation of the European Structural and Investment Funds (ESIF)

To gain deeper understanding of public support in Lithuania, it is essential to discuss the amounts disbursed to early-stage solar energy startups.

The agreement between the EU and Lithuania did not include a specific goal to encourage early-stage solar energy startups (European Commission 2014). In 2014-2020, the total ESIF of Lithuania was EUR 7,224,878,740.00 (ES Investicijos 2014).

The Lithuanian government distributed the ESIF funds based on 11 of the EU's and Lithuania's national priorities, as discussed in the literature review (Chapter 2). 10.12% of ESIF funds in Lithuania were dedicated to encouraging innovation, focusing on the commercialization of the R&D&I, and knowledge transfer to stimulate private investments (European Commission 2014). Additionally, 7,92% of total funds were dedicated to supporting small and medium-sized enterprises' (SMEs) competitiveness and innovation (European Commission 2014).

The priorities that encouraged the funding of solar energy early-stage startups are Priority 1 (aiming to "stimulate research, experimental development, and innovation") and Priority 3 (seeking "to promote the competitiveness of small and medium-sized enterprises") (CPVA 2018, ES Investicijos 2014). The total funding allocated to Priority 1 was EUR 802,328,835.00 and EUR 597,703,253.00 were allocated to Priority 3 (ES Investicijos 2014).

These priorities were funded solely with the EU's budget (no national contribution) and private co-funding, which indicates that Lithuania's public support for innovation is dependent on the EU and project developers (Interviewee 15 2021). To help understand the ESIF distribution in more detail, the ESIF finance flow is assessed further in the following chapters.

7.2 Funding Distribution to Early-stage Solar Energy Startups in Lithuania

Funding distribution to early-stage solar energy startups in Lithuania is presented in a Sankey diagram (Fig. 12). The diagram displays the finance flow of Priority 1 and Priority 3 in four dimensions: source, priority, instrument, and user. The diagram shows that most funding came from private co-funding, and the rest was covered by the EU budget (Fig. 12). The instruments included in the diagram (Fig. 12) are solely those that are relevant to financing solar energy innovation. The finance flow diagram does not show intermediaries and funding type because they are identical for all users. The analyses revealed that the type of funding for all final users were grants, and the intermediary for all users was the Lithuanian Business Support Agency (ES Investicijos 2014). The final beneficiaries (users) of the ESIF funding were early-stage solar energy businesses or early-stage solar energy business-science cooperations.

The analysis showed that the overall amount distributed to early-stage solar energy startups in Lithuania is meager. It was observed that 1,3% of Priority 1 and 0,03% of Priority 3 funds were distributed to the solar energy business and business-science cooperation R&D&I startups. Most of the funding for early-stage startups was received through the instruments "Eksperimentas" and "Intelektas. Bendri mokslo ir verslo projektai" (Fig. 12). During the ESIF 2014-2020 financing period, specific attention to solar energy early-stage startups was limited, due to the prioritization of strategy development instead of focusing on solar energy innovation support:

> Lithuania's government priority was to create a strategy and legal basis for the development of innovation in the whole clean energy sector. For this reason, Lithuania's government did not divide the clean energy industry into sectors such as solar energy and solar energy innovation was not prioritized in 2014-2020 (Interviewee 4 2021).

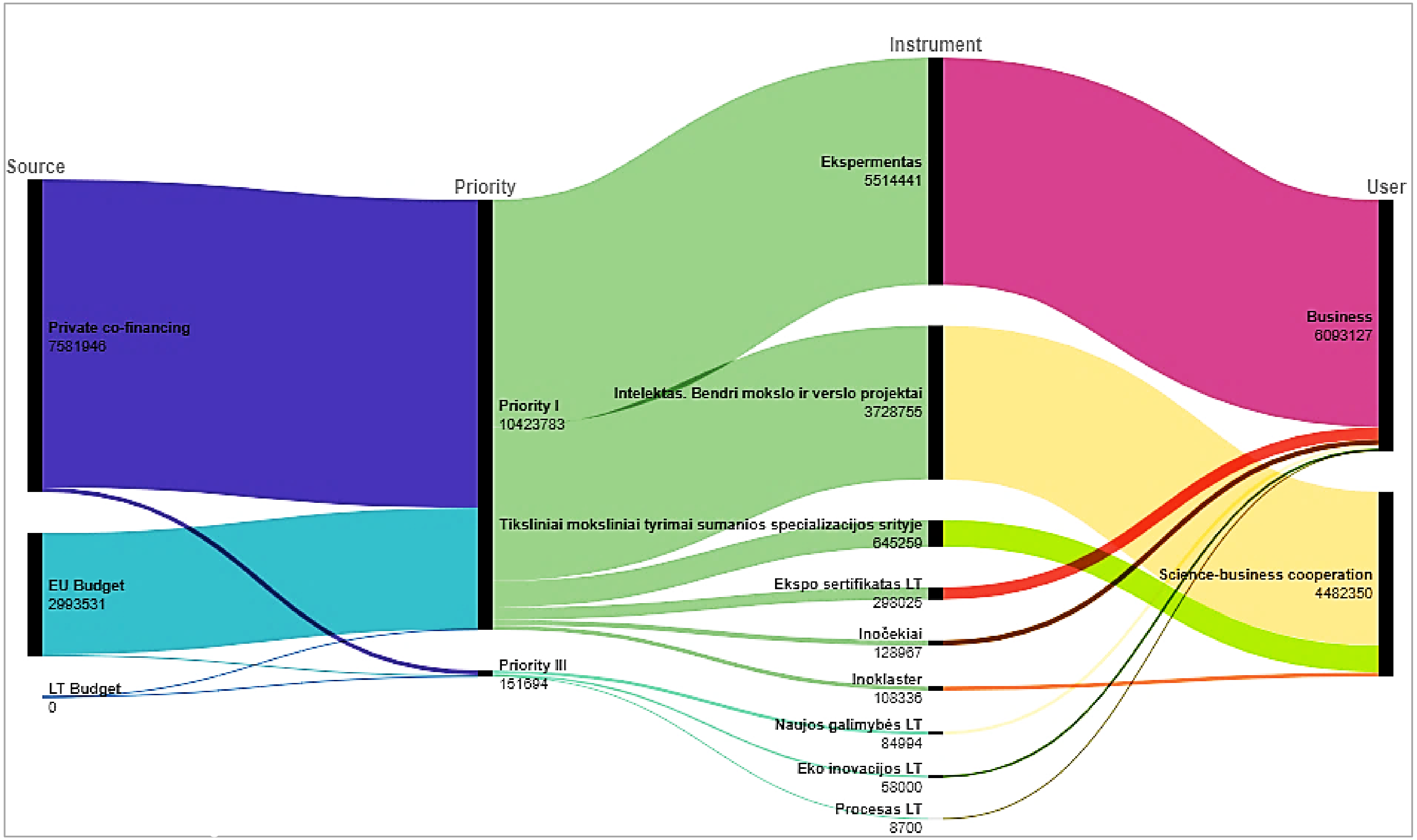

Figure 12: Finance flow of the public and private co-funding of solar energy early-stage startups in Lithuania in 2014-2020 (EUR).
Data source: ES Investicijos (2014)

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7.3 Lessons Learned from Funding Distribution

The lessons from the 2014-2020 ESIF programming period were assessed in order to draw recommendations for improving public support for early-stage solar energy startups in Lithuania. Based on the analysis, the critical lessons learned include lack of investment in solar energy innovation, lack of international networking, lack of cooperation among early-stage startups, the importance of consistent strategy, and the public funding instruments' focus on increasing solar capacity but not on developing innovative technologies.

7.3.1 Lack of Investments

The lack of investments is observed not only in solar energy innovation but in innovations in general. According to the European Innovation Scoreboard 2017, Lithuania rose to 16th place in innovation investments (Kauno Technologijos Universitetas 2015). This growth was the fastest in the EU, a 21% increase in one year. Despite positive developments, Lithuanian investment in R&D&I remained well below the EU average, creating a gap between innovation demand and supply (Kauno Technologijos Universitetas 2015). In 2017, the investment in innovations in Lithuania was 0.89%, less than half compared to the EU's average (2.06%) (Visionary analytics and Ministry of Economic and Innovation of the Republic of Lithuania 2019). In the same year, the ratio of Lithuanian private investments to R&D&I was more than four times lower than the EU average (0.31%, compared to 1.36%) (Visionary analytics and Ministry of Economy and Innovation of the Republic of Lithuania 2019). The slow investments in solar energy early-stage startups can be associated with the government's priority to build a strategy, legal system, and ecosystem before boosting the investments in solar energy innovation:

> The support for solar energy innovation was put in second place due to limited resources. Despite the limited support in the solar energy generation sector was, the political and legal basis for future development was created. I believe that the present year is the best for solar energy early-stage innovation support (Interviewee 4 2021).

7.3.2 Lack of International Networking

In 2014-2020 Lithuania lacked activities to help innovative companies improve access to international markets. Some elements of internationality are integrated into the “Inoklaster LT” (Eng. “Inoclaster LT”) instrument. Also, an instrument "InoConnect" promoted international partnerships and networking through the European Business and Innovation Network. These instruments aimed to increase the startups opportunities to participate in global EU R&D&I initiatives, establish links with international partners, and attract investors (Visionary analytics and Ministry of Economic and Innovation of the Republic of Lithuania 2019).

7.3.3 Lack of Cooperation Among Early-stage Startups

The lack of cooperation between early-stage startups in 2014-2020 was also observed. The collaboration of startup companies brings economic benefits and fosters cross-sectoral (especially science and business) synergies (Visionary analytics and Ministry of Economy and Innovations of the Republic of Lithuania 2019). Solar energy startup cooperation allows solving of complex projects while utilizing fewer resources (Interviewee 6 2021). The instruments did not focus on strengthening the linkages in the clean energy ecosystem. Although some measures such as “Inočekiai” promoted short term cooperation, the overall impact was limited (Visionary analytics and Ministry of Economic and Innovations of the Republic of Lithuania 2019).

7.3.4 The Importance of Consistent Strategy

A consistent political strategy for boosting the support of solar energy innovation is essential for innovation development (Kauno Technologijos Universitetas 2015). It is important to highlight that the trust of investors is strongly influenced by the commitments of political leaders, which determine where the funds will be invested. In Lithuania, a stable strategy for solar energy development was created in 2018 (National Energy Independence

Strategy). It is important to highlight that the strategy did not set specific support goals for each clean energy sector (e.g., solar energy sector). However, in 2020, an agreement for developing "Hydrogen Platform" was signed between the Ministry of Energy of the Republic of Lithuania, Ministry of Economy and Innovation of the Republic of Lithuania, Ministry of Transport and Communications of the Republic of Lithuania and the State Energy Regulatory Council as well as semi-private and private companies "EPSO-G", "Ignitis Group", "Klaipėdos Nafta", "Amber Grid", "Orlen Lithuania", "Achema", "SG dujos", "Contrarian Ventures", and associations (Butkus 2020). Besides that fund, there are no specific funds dedicated to other clean energy sectors (Interviewee 8 2021).

7.3.5 Increasing Solar Power Capacity but not Investing in Innovative Technologies

The financial instruments were more suitable for solar energy innovation companies that focused either on reducing GHG emissions or speeding up the development of PV power plants (ES Investicijos 2014). Increasing solar capacity enlarges the number of solar power plants, however without technological innovation the quality and efficiency of solar energy harvesting is not improved. Due to lower efficiency, the actors that focus on innovations and high-quality technologies are left aside because of price differences (Interviewee 6 2021).

8. Improving Public Support for Solar Energy Early-stage Startups in Lithuania

8.1 Improving Public Finance Distribution to Solar Energy Early-stage Startups

This chapter discusses the possible improvements of finacial support instruments in the context of the needs of early-stage startups and the lessons learned from the previous ESIF funding period.

The main issue associated with funding is that the instruments' eligibility criteria and administration costs are unsuitable for early-stage startups. Despite the available public funding, *Airion* cannot access funding due to high eligibility requirements. A fundamental improvement would be developing financial tools suited to help early-stage startup companies build their prototypes and attract their first clients (Interviewee 15 2021). For example, for *Airion,* the improvements in adapting eligibility criteria to startups possibilities could help gain much-needed funds for the entire prototype building, which is necessary to attract the first clients.

One of the main instruments dedicated to early-stage startups is “Inostartas“. However, access to “Inostartas“ is limited for early-stage innovators because it is focused on startups that have already developed a prototype of the product. In addition, “Inostartas“ funding is only provided to the startup company after completion of the project. For this reason, early-stage innovators are not able to participate due to a lack of funds or hesitation to take a risk if their activities fail (Visionary Analytics and Ministry of Economy and Innovation of the Republic of Lithuania 2019).

To improve funding disbursement mechanisms, Interviewee 3 (2021) suggests communicating openly with startups to understand what kind of funding criteria would be more adequate for early-stage startups. Funding options should be more adaptable so that early stage startups can actually reach them. In addition, Interviewee 15 (2021) suggest changing the eligibility criteria to more accessible possibilities for startup companies. For example, to evaluate the background of founders instead of assessing the assets owned or annual turnover.

8.2 Strengthening the Ecosystem of Solar Energy Early-stage Startups in Lithuania

Based on the Lithuanian startup ecosystem analysis (Ratkevičiūtė *et al.* 2020), there are eleven elements of the ecosystem in Lithuania: communications, culture, human resources, legal environment, consumers, funding, products and services, infrastructure, science, and technology (Ratkevičiūtė *et al.* 2020). The ecosystem elements that lack improvement in Lithuania are human resources and culture.

In terms of human resources, the renewable energy-related programs are taught in eight institutions (Kaunas University of Technology, Vilnius Gediminas Technical University (Vilnius Tech), University of Klaipėda, Vilnius College of Technology and Design, Kaunas Technology College, College of Utena). Despite the existence of renewable energy engineering studies, other energy innovation and commercialization-related study fields need to be developed (Ratkevičiūtė *et al.* 2020). Interviewee 15 (2021) argues that in addition to the number of students, the whole education system in Lithuania needs to become innovation oriented. For *Airion* the lack of human resources is not an issue yet, as the project is under the founding stage and not acceleration but finding employees in the future could be challenging.

Another element of the ecosystem that could be strengthened is culture. Culture is a comprehensive term that has various definitions. For *Airion*, culture is associated with networking, interactions, and mentorship. The latest is essential because existing team members are from the tech and environmental science and policy fields. Hiring a CEO is not an option for *Airion* because it is an early-stage innovator, which is still under the break-even point, meaning *Airion* does not have an annual turnover. Specific instruments of the ESIF funds could be dedicated to creating a program that encourages mentoring for early-stage startups.

Currently, a private mentoring program exists, but it is dedicated to women who are willing to enter the tech field – "Women go Tech." For this program, women from different fields are selected based on their motivation to develop their careers in the tech field. A similar model could be adapted for solar energy startups in Lithuania.

According to Interviewee 12 (2021), creating an ecosystem is more complex than financing solar energy startup companies. Developing the ecosystem requires finance and focus on legal and educational support and mentoring programs related to business and team management. Based on Interviewee 12 (2021), engineers usually understand technology but lack skills in business management. The lack of business management experience increases the risk of entering the valley of death (VoD):

> You can have an excellent idea of management and financial aspects, but if you do not have an outstanding team in place and proper support in place, from a financial management perspective, you are going nowhere. You need to take broad and consistent actions to develop thriving startup ecosystem (Interviewee 17 2021).

8.3 Encouraging Collaboration Between Startup Companies

The cooperation of startup companies brings economic benefits and fosters cross-sectoral synergies (Visionary Analytics and Ministry of Finance of the Republic of Lithuania 2017). However, it seems that the existing public support opportunities for encouraging partnerships among early-stage startup companies are lacking in Lithuania.

In 2014-2020, the instruments did not focus on strengthening the linkages in the solar energy ecosystem. Although some measures, such as “Inočekiai” promoted collaboration in the short term, the overall impact was limited (Visionary Analytics and Ministry of Finance of the Republic of Lithuania 2017).

For *Airion*, partnerships could help find co-founders with more knowledge in business development and decrease the costs of processes that need to be implemented during product development, such as product testing.

To improve early-stage startup collaboration, common spaces with necessary equipment could be developed. Such spaces have been created in Finland. For example, "Sitra" collaboration space provides a cross-sectoral collaboration area for clean energy startups, a training program for early-stage startups, a laboratory space with necessary equipment, and community building encouragement (Sitra n.d.). Similar lab spaces are created in Lithuania, such as Vilnius Gediminas Technical University (Vilnius Tech), but these spaces are more dedicated to mature startups (Interviewee 6 2021).

8.4 Maintaining Political Stability Towards Solar Energy Innovation

Political interest and long-term strategy dedicated to developing solar energy innovation in Lithuania can help guarantee funding. For *Airion*, knowing about future funding opportunities could help the company make more risky decisions (GSDRC 2021). As one of the main improvements, Interviewee 4 (2021) suggests that funding should be specifically allocated to clean energy by sector (i.e., wind, solar, etc.). He suggests that this would help improve the funding application processes and bring more clarity to businesses. However, Interviewee 2 (2021) argues that it is better to allocate funds specifically to clean energy without a sectoral division:

> Allocating funds specifically to green power could be a better solution because it can help in establishing new innovative ways to produce clean energy and avoid innovation gap.

8.5 Expected Improvement Outcomes

It is vital to acknowledge how the suggested support can help solar energy startups in the future. Fig. 13 illustrates how these improvements and desired outcomes can encourage solar energy innovation in Lithuania based on the theory of change discussed in the literature review. Fig. 13. displays the drivers of change that were developed based on the needs of the early-stage solar energy startups in Lithuania, and the lessons learned from the previous ESIF programming period in 2014-2021.

In the chart (Fig. 13) each driver of change creates a desired outcome, such as adapting ESIF instrument criteria to the possibilities of early-stage startups in Lithuania, which can help more early-stage startups apply for funding and overcome the VoD (European Commission n.d.b). Additionally, instruments created particularly for startup collaboration and international networking could help startups solve more complex problems and encourage international cooperation and idea transfer (Interviewee 15 2021, Interviewee 6 2021). Furthermore, promoting open communication and discussion with the founders of early-stage startups could help understand the needs and perspectives of early-stage startups and which instruments are better suited for these startups' development (Interviewee 3 2021).

What is more, pre-acceleration and acceleration programs are dedicated to developing a prototype or business model, gaining connections, and presenting an idea to potential investors (Energypreaccelerator.lt 2020). For this reason, an increased amount of pre-acceleration and acceleration programs could help startup companies develop their prototypes, as well as develop business models that are less likely to cause the startup to fall into the VoD. Another driver of change includes maintaining political stability, which could encourage investments from the private sector (GSCRC 2021).

Finally, enhancing the ecosystem could help in strengthening networking and connections with investors and partners, which can result in successful business management mentorship, which is especially needed for early-stage startups (Hubbub Labs 2017).

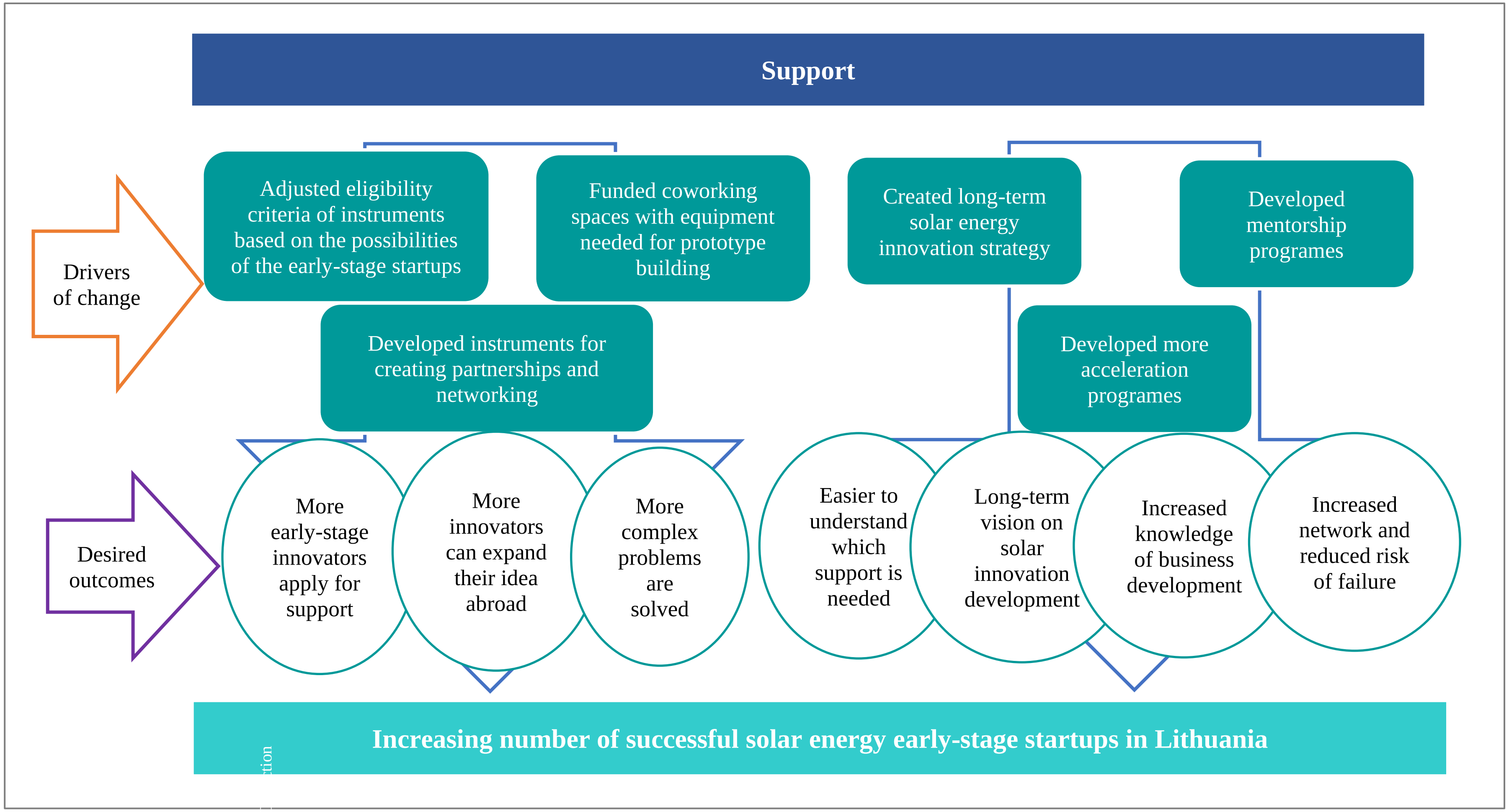

Figure 13: Theory of change for encouraging the solar energy early-stage startups' development in Lithuania.
Source: Author according to guidelines of (NPC 2014)

9. Summary of Findings

The following section summarizes the findings related to the needs of startups, the role of governmental support, the lessons drawn from the 2014-2020 ESIF period, and the key improvements needed to better support early-stage solar energy startups in Lithuania.

9.1 The Needs of Early-stage Startups

Based on the analysis, the needs of early-stage solar energy startups included:

- Pre-seed Funding:

  Pre-seed funding is needed to hire a team, to purchase office equipment for developing a prototype, gaining certifications, reaching clients, and being eligible for public support. A dedicated team is one of the main elements of successful startups, because it allows for consistency in product development, and pre-seed funding can help teams stay focus on development process. In addition to the team members' salaries, the workplace requires pre-seed funding, office space and equipment. Also, pre-seed funding is vital for gaining the certification of the products because products that are not certified may not be able to gain customers. Furthermore, pre-seed funding is crucial for reaching clients and investors. Pre-seed funding is also essential for being eligible for public support. Most early-stage solar energy startup companies do not qualify for public support due to low annual turnover, insufficient assets, or high administration costs.

- Mentorship:

  Mentorship is also essential for early-stage startups. Early-stage startups operating in the solar energy field are often knowledgeable in technology but have little knowledge in business management. Mentorship programs could help startups learn about business management and expand their network.

- Collaboration:

  Public-private partnerships can help gain financing for the development of the full product and learn about the needs of clients.

9.2 The Role of Government in Supporting Early-stage Solar Energy Startups and Available Support in Lithuania

Public support for early-stage solar energy startups includes the pre-acceleration programs, science park services, consultations, and financial support. However, only pre-acceleration programs were accessible for the pilot project.

The government plays a vital role in developing a strategy such as the National Energy Independence Strategy, founded in 2018. In addition, the government legalized the term of the regulatory sandbox that helps solar energy early-stage startups test their products without additional legal burdens. Also, government plays an essential role in providing grants until they reach commercialization. However, it was observed that financial support usually does not reach early-stage startups due to eligibility criteria that are more suitable for mature startups.

9.3 Lessons learned from support in 2014-2020

Throughout the analysis, five lessons learned were drawn and are presented further:

- Lack of Investments

  A lack of investments was observed not only in solar energy innovation but in innovation in general. The main reason for the lack of investments in solar energy innovation is the government's aim to develop a strategy before encouraging innovation.

- Lack of International Networking

  Throughout the 2014-2020 period, the lack of incentives for international networking was observed. Some instruments such as “Inoklaster LT” and “InoConnect” were dedicated to increasing global networking, but the impact was short-term.

- Lack of Cooperation Among Early-stage Startups

  The lack of instruments focusing on strengthening the linkages of the early-stage startups were observed. Some instruments, such as “Inočekiai” focused on collaboration but were not effective.

- The Importance of Consistent Strategy

  The consistent strategy is important for maintaining financial support and other support systems and helping early-stage startups make more risky decisions.

- Dedication to Increase Solar Power Capacity and not Innovation.

  In the past ESIF programming period, government focused more on the increasing the capacity of solar power generation, and less attention was paid to developing solar energy innovation.

9.4 Key Improvements

To strengthen the public support for an early-stage startups, key improvements include:

- Adapting Funding Criteria for Early-stage Startups

  The requirements for the early-stage startups could include the background check of the founders instead of a specific amount of assets owned or annual turnover.

- Strengthening the Ecosystem

  Strengthening the solar energy ecosystem could include the increased capacity of pre-acceleration, acceleration programs, business mentorship programs, and improvements in the solar energy education system.

- Increasing Collaboration Capacity

The collaboration spaces could be financed to increase cooperation among startups, which would have all the necessary equipment for building prototypes and complex problem solving.

- Maintaining consistent strategy

In addition to the current strategy, a long-term strategy dedicated to clean energy or solar energy innovation could be developed, which would help startup companies to take more risky decisions.

10. Discussion

This discussion connects between the analytical theories and concepts presented in Chapter 2, and the research findings, in order to point out the best policy recommendations for supporting early-stage solar energy startups in Lithuania.

The first theory to be discussed is the Schoen *et al.* (2005) innovation model which illustrates that innovation is a long and complex process. This process and complexity were recognised throughout the case study. The *Airion* study highlights how developing a novel product or service in the solar energy field involves experimenting, failing, and learning from mistakes. Throughout *Airion's* experience, the development of an idea and the first part of the prototype took approx. six months, and it is not completed yet, because after printing the prototype model, it was recognized that the model's design is not customer friendly, and improvements of the prototype design need to be made to increase functionality. Although the experimentation process is necessary for adapting the product for customer needs, early-stage solar energy startups often do not have the funds to sustain themselves throughout the experimentation process. Since innovation takes time, experimentation, failure and success, early-stage startups require funds in order to complete the process of innovation. For this reason, access to public support for early stage startups is essential.

The next theory, by Mazuccato and Semieniuk (2017) suggest that public support can guarantee finance flow-through grants before private investors are willing to invest in an early-stage startup. However, findings show that even though public support is available in Lithuania, it is rarely accessible to early-stage solar energy startups. Findings from the *Airion* pilot project and interviews with solar energy startup founders, illustrate that public support for early-stage startups in Lithuania does not reach the startups due to financial grants eligibility criteria and administration costs. It should be acknowledged that eligibility requirements for gaining public financial support are crucial for avoiding illegal activities or startups fabricating innovation development processes. However, the current eligibility requirements create a barrier for early-stage startups and slows the appearance of innovation due to lack of funding, which contributes to the slowdown or cut of product development. For this reason, it is essential to adapt the financial instrument criteria to the adequate possibilities of early-stage solar energy startups in Lithuania (e.g. requirements could include the background check of founders (Interviewee 15 2021)).

All startups are trying to avoid falling into the Valley of Death (VoD) in order to reach commercialization. This concept is illustrated by the Diffusion of innovation (DoI) theory. Findings show that there are several ways to help startups avoid the VoD. Providing direct grants to startups is not the only way to keep them afloat. Other means of support could be investing ESIF in collaboration spaces specifically dedicated to early-stage solar energy startups. These spaces could provide a place for collaboration, sharing business advice, shared laboratory space and networking opportunities, offer free necessary equipment to develop a prototype or minimum viable product (MVP), which can all support early-stage startup development, as shown in the findings. Although collaboration spaces are often understood as physical places, collaboration among startups can develop a social community. For example, Mitev *et al*. 2018 suggest that collaboration practices and coworking spaces can create a space for emotional support and encourage a sense of belonging. Based on *Airion's* experience, product and business development is a stressful process, and discussing the challenges with other co-workers from early-stage startups can reduce stress and build social bonds. Allocating funds for collaboration spaces can also avoid the disbursement of funds to falsify startups, since the grants are not being directly gifted.

Findings also show that mentorship for early stage startups can significantly help avoid falling into the VoD. For *Airion,* having a mentor from the business field would be a great assistance since the current team members do not have a business background or experience.

11. Conclusions and Recommendations

This thesis explored public support for early-stage solar energy startups in Lithuania from 2014 to the present (last Cohesion Policy and European Structural Investment Funds (ESIF) programming period). This was done by researching theories, interviewing experts and startup founders and launching a pilot project. The needs of early-stage solar energy startups were then analysed according to the findings. Findings showed that the risk of falling into the valley of death (VoD) for early-stage solar energy startups is very high. To help these startups, Lithuania offers various support measures including pre-acceleration programs, consultations, and ESIF financing. However, the available public support does not necessary fulfil the specific needs of early-stage solar energy stratups. Therefore. the following policy recommendations are made:

1. Adapt eligibility criteria of the ESIF financial instruments to the possibilities of early-stage startups:

Fulfilling grants eligibility criterias was complicated for the early-stage stratups because early-stage innovators are usually under the break-even point. For this reason it is reccomended to adapt grants‘ criteria.

2. Increase the capacity of mentorship and networking programs dedicated to solar energy innovation and commercialization:

Mentorship programs are essential in teaching technology startup founders about business development and guiding their way to overcoming the VoD. In addition, networking helps expand to the markets abroad and find advisors and potential customers.

3. Develop collaborations spaces dedicated to early-stage solar energy startups:

Invest ESIF into the collaboration spaces accessible for solar energy early-stage startup companies could help startups collaborate and solve complex challenges. Collaboration spaces could also help early-stage startup companies build prototypes essential for finding customers and investors as well as create a solar energy innovation community.

Developing solar energy early-stage startup communities, mentorship programs, and adjusting eligibility criteria for funding, could be the main focus of fund allocation in the next ESIF programming period (2021-2027). However, further research is still needed to define these ideas more specifically. For example, the exact kind of collaboration spaces and mentorship programs that can specifically increase solar energy innovation development are still unknown.

References

Agency for Science, Innovation and technology (MITA). 2020. Paslaugos startuoliams [Services for startups]. Accessed May 23 2021. URL: https://mita.lrv.lt/lt/paslaugos/paslaugos-startuoliams

_________. 2021. Startuolių verslas ir rinkodara: ką daryti, kad idėja neužstrigtų stalčiuje [Start-up business and marketing: what to do to keep the idea from getting stuck in a drawer]. Accessed May 23 2021. URL: https://mita.lrv.lt/lt/naujienos/startuoliu-verslas-ir-rinkodara-ka-daryti-kad-ideja-neuzstrigtu-stalciuje

_________. 2021a. Inostartas. Accessed May 2021. URL: https://mita.lrv.lt/lt/veiklos-sritys/programos-priemones/inostartas

_________. 2021b. Konsultacijos [Consultations]. Accessed May 23 2021. URL: https://mita.lrv.lt/lt/veiklos-sritys/mita-vykdomi-projektai/gyvyb%C4%97s-mokslu-industrijos-pletros-skatinimas/konsultacijos

_________. 2021c. TechHub. Accessed May 23 2021. URL: https://mita.lrv.lt/techhub

Armada IP Capital. 2019. Small businesses and startups are still the main drivers of innovation. Accessed May 20 2021. URL: https://armadaip.com/small-businesses-and-startups-are-still-the-main-drivers-of-innovation/

Audretsch, D. B. Bonte, W. Mahagaonkar, P. 2012. Financial signalling by innovative nascent ventures: the relevance of patents and prototypes. *Research Policy* 41(8): 1407-1421.

Banton, C. 2020. Interest rate. Investopedia. Accessed May 24 2021. URL: https://www.investopedia.com/terms/i/interestrate.asp

Baum, J. A. C. Calabrese, T. Silverman, B. S. 2000. Don‘t go alone: allience network composition and startups‘ performance in Canadian biotechnology. *Strategic Management Journal* 21: 267-294.

Blom Bank Group. 2014. The valley of death. Blog article. Accessed May 20 2021. URL: https://blog.blominvestbank.com/2950/the-valley-of-death/

Bluszcz, A. 2017. Europe economies in terms of energy dependence. *Qual Quant* 51: 1531--1548.

Bolt. 2021. Startuolio genas: 5 būdai, kaip nuveikti daugiau išleidžiant mažiau [Startup gene: 5 ways to do more by spending less]. Accessed May 23 2021. URL: https://blog.bolt.eu/lt/startuolio-genas-5-budai-kaip-nuveikti-daugiau-isleidziant-maziau/

Butkus, L. 2020. Lietuvoje kurs vandenilio platforma [A hydrogen platform will be built in Lithuania]. Accessed May 24 2021. URL: https://www.vz.lt/transportas-logistika/2020/11/30/lietuvoje-kurs-vandenilio-platforma

Cbinsights. 2020. Top investors fueling the renewable energy tech ecosystem. Research brief. Accessed May 20 2021. URL: https://www.cbinsights.com/research/renewable-energy-tech-ecosystem-top investors/#:~:text=Shell%20Ventures%2C%20EIT%20InnoEnergy%2C%20Energy,in%20the%20renewable%20energy%20ecosystem

Central Project Management Agency (CPVA). 2018. 2014-2020 EU investments in Lithuania. Accessed May 24 2021. URL: https://www.cpva.lt/en/2014-2020-eu-investment-in-lithuania/453

Cho, S. Mathiassen, L. Gallivan, M. 2008. Open IT-based innovation: moving towards cooperative IT transfer and knowledge diffusion. International Federation for Information Processing 287: 361-378.

Collins, M. Knutti, R. Arblaster, J. Dufresne, J. L. Fichefet, T. Friedlingstein, P. Gao, X. Gutowski, W.J. Johns, T. Krinner, G. Shongwe, M. Tebaldi, C. Weaver A. J. Wehner, M. 2013. Long-term Climate Change: Projections, Commitments and Irreversibility. Cited in: Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York: Cambridge University Press.

Corporate Finance Institute (CFI). 2021. Breakeven point (BEP). Accessed May 23 2021. URL: https://corporatefinanceinstitute.com/resources/knowledge/finance/break-even-point-bep/

_________. n.d. ROI formula (Return on Investment). Accessed May 20 2021. URL: https://corporatefinanceinstitute.com/resources/knowledge/finance/return-on-investment-roi-formula/#:~:text=Return%20on%20investment%20%28ROI%29%20is%20a%20financial%20ratio,net%20income%20divided%20by%20the%20original%20capital%20cost

Dževerskytė, R. 2020. Startuoliams siūlo kreiptis į mentorius [An offer for startups: ask mentors]. Accessed May 23 2021. URL: https://www.vz.lt/smulkusis-verslas/2020/10/01/startuoliamssiulo-kreiptis-i-mentorius

Edler, J. Fagerberg. J. 2017. Innovation policy: What, why, and how. *Oxford Review of Economic Policy* 33 (1): 2-23.

Energija Man. 2020. Saulės elektrinės kaina. Kiek kainuoja Lietuvoje? [The price of solar power plant. How much it costs in Lithuania?]. Accesses May 23 2021. URL: https://energijaman.lt/naujienos/saules-elektrines-kaina/

Energypreaccelerator.lt. 2020. 1.7. Venture capital funds, acceleration and pre-acceleration programs operating in Lithuania. Accessed May 20 2021. URL: https://energypreaccelerator.lt/courses/energy-pre-accelerator-program/lessons/presentation-of-venture-capital-funds-and-acceleration-and-pre-acceleration-programs-operating-in-lithuania/

ES Investicijos. 2014. *Priemonės pagal prioritetą* [Measures based on priority]. Accessed May 23 2021. URL: https://www.esinvesticijos.lt/lt/patvirtintos_priemones/listingItem_byPriority

_________. 2014a. *Finansavimo skyrimo, vertinimo ir įgyvendinimo schemos* [Funding allocation, evaluation and implementation schemes]. Accessed May 23 2021. URL: https://esinvesticijos.lt/lt/finansavimas/finansavimo-skyrimo-schema

ES Paramos. 2021. Inočekiai LT. Accessed May 23 2021. URL: https://www.esparamos.lt/es-parama-moksliniams-tyrimams-ir-technologinei-pletrai/inocekiai-lt/

European Commission. 2014. Operational Programme for EU Structural Funds Investments for 2014-2020: Lithuania. Accessed May 23 2021. URL: https://ec.europa.eu/regional_policy/en/atlas/programmes/2014-2020/europe/2014lt16maop001

_________. 2014a. Cohesion Policy and Lithuania. Accessed May 24 2021. URL: https://ec.europa.eu/regional_policy/sources/information/cohesion-policy-achievement-and-future-investment/factsheet/lithuania_en.pdf

_________. 2016. D1.2 Regulatory framework. Accessed May 28 2021. URL:

https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5acc95e9f&appId=PPGMS
_________. 2020. Powering a climate-neutral economy: Commission sets out plans for the energy system of the future and clean hydrogen. Accessed May 14 2021. URL: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1259
_________. 2020a. In focus: Renewable Energy in Europe. News. Accessed May 21 2021. URL: https://ec.europa.eu/info/news/focus-renewable-energy-europe-2020-mar-18_en
_________. 2020b. Energy. European Union. Accessed May 21. URL: https://ec.europa.eu/energy/topics/energy-strategy/energy-union_en
_________. 2020c. A European Green Deal: Striving to be the first climate neutral continent. Accessed May 21 2021. URL: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
_________. 2020d. The European Green Deal Investment Plan and Just transition mechanisms explained. Accessed May 21 2021. URL: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24
_________. 2020e. Soalr energy: Why the EU supports solar energy research and innovation. Accessed May 21 2021. URL: https://ec.europa.eu/info/research-and-innovation/research-area/energy-research-and-innovation/solar-energy_en#:~:text=Solar%20energy%20is%20energy%20derived%20from%20the%20sun.,EU-28%20gross%20electricity%20generation%20in%202017%20%28source%3A%20Eurostat%29.
_________. n.d. Climate Action. Accessed May 23 2021. URL: https://ec.europa.eu/clima/policies/strategies/2020_en#tab-0-0
_________. n. d.a. Priorities for 2014-2020. Accessed May 27 2021. URL: https://ec.europa.eu/regional_policy/en/policy/how/priorities
_________. n.d.b. Connecting Europe facility (CEF) – Financial instruments. Accessed May 20 2021. URL: https://ec.europa.eu/info/business-economy-euro/growth-and-investment/financing-investment/connecting-europe-facility-cef-financial-instruments_en
Flick, U. 2018. Generating Qualitative data with experts and elites. SAGE research methods. Accessed May 23 2021. URL: http://mr.crossref.org/iPage?doi=10.4135%2F9781526416070
Fruhlinger, J. 2020. What is IoT? The internet of things explained. Accessed May 23 2021. URL: https://www.networkworld.com/article/3207535/what-is-iot-the-internet-of-things-explained.html
Georgeson, L. Maslin, Maslin, M. Poessinouw, M. 2016. Clean up energy innovation. *Nature*. Accessed May 20 2021. URL: https://www.nature.com/news/clean-up-energy-innovation-1.20718
Given, L. M. 2008. Semi-structured interview. SAGE research methods. Accessed May 23 2021. URL: https://methods.sagepub.com/reference/sage-encyc-qualitative-research-methods/n420.xml
_________. 2008a. In Vivo Coding. SAGE research methods. Accessed May 23 2021. URL:http://methods.sagepub.com/reference/sage-encyc-qualitative-research-methods/n240.xml
Governance and Social Development Resource Centre (GSCRC). 2021. Credible government commitments. Accessed May 26 2021. URL: https://gsdrc.org/topic-guides/state-business-relations/drivers-of-success/credible-government-commitments/
Grubler, A. Willson, C. 2014. *Energy technology innovation: learning from historical successes and failures.* New York: Cambridge University Press.

Hainaut, H. Gouiffes, L. Cochran, I. 2017. Landscape of Climate Finance in France. Accessed May 23 2021. URL: https://www.i4ce.org/wp-core/wp-content/uploads/2017/12/1212-I4CE2772-Decideurs-VA-web.pdf

Heaton, J. 2019. Secondary analysis of Qualitative Data. SAGE research methods. Accessed May 23 2021. URL: https://methods.sagepub.com/foundations/secondary-analysis-of-qualitative-data

Hubbub Labs. 2017. What is a startup ecosystem and how can you build up one?. Accessed May 24 2021. URL: https://hubbublabs.com/the-insider/startup-ecosystem/

In, S.Y. Monk, A.H.B. Knox-Hayes, J. 2020. Financing Energy Innovation: The Need for New Intermediaries in Clean Energy. *Sustainability 12 (24):* 1-25.

Integruotos augalų apsaugos informavimo, konsultavimo ir mokymo informacinė sistema (IKMIS). n.d. accessed May 23 2021. URL: https://www.ikmis.lt/Bundles/

International Energy Agency (IEA). 2019. Innovation Gaps. Accessed May 14 2021. URL: https://www.iea.org/reports/innovation-gaps/renewable-power

_________. 2020a. World Energy Outlook 2020. Accessed May 14 2021. URL: https://www.iea.org/reports/world-energy-outlook-2020

_________. 2020b. Solar. Accessed May 14 2021. URL: https://www.iea.org/fuels-and-technologies/solar

_________. 2020c. Clean Energy Innovation. Flagship report. Accessed May 20 2021. URL: https://www.iea.org/reports/clean-energy-innovation

_________. 2020d. The impact of the Covid-19 crisis on clean energy progress. Article. Accessed May 20 2021. URL: https://www.iea.org/articles/the-impact-of-the-covid-19-crisis-on-clean-energy-progress

_________. 2020e. Global status of clean energy innovation. Accessed May 20 2021. URL: https://www.iea.org/reports/clean-energy-innovation/global-status-of-clean-energy-innovation-in-2020

_________. 2020f. Installed power generation capacity by source in the stated policies scenario, 2000-2040. Accessed May 21 2021. URL: https://www.iea.org/data-and-statistics/charts/installed-power-generation-capacity-by-source-in-the-stated-policies-scenario-2000-2040

International Energy Agency and European Patent Office (IEA and EPO). 2021. Patents and the energy transition: global trends in clean energy technology innovation. Accessed May 20 2021. URL: https://documents.epo.org/projects/babylon/eponet.nsf/0/3A283646135744B9C12586BF00489B38/$FILE/patents_and_the_energy_transition_study_en.pdf

International Renewable Energy Agency (IRENA). 2019. Innovation landscape for a renewable-powered future: solutions to integrate variable renewables. Accessed May 20 2021. URL: https://www.irena.org/publications/2019/Feb/Innovation-landscape-for-a-renewable-powered-future

_________. 2020. Renewable power generation costs in 2019. Accessed May 20 2021. URL: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jun/IRENA_Costs_2019_EN.pdf?la=en&hash=BFAAB4DD2A14EDA7329946F9C3BDA9CD806C1A8A#:~:text=Power%20generation%20costs%20in%202019%20were%20around%20USD%200.073%2FkWh,cost%20range%20for%20new%20capacity.

Investopedia. 2020. Market failure. Accessed May 24 2021. URL: https://www.investopedia.com/terms/m/marketfailure.asp

Kauno Technologijos Universitetas. 2015. Lietuvos ekonomikos ilgalaikio konkurencingumo iššūkiai: apibendrintos tyrimų įžvalgos ir rekomendacijos [Challenges of long-term competitiveness of the Lithuanian economy: generalized research insights and recommendations]. Accessed May 24 2021. URL: https://www.lmt.lt/data/public/uploads/2016/09/ekonomikos-moksliniu-tyrimu-programos-rekomendacijos.pdf

Kelly, J. M. Schaan, J. L. Joncas, H. 2002. Managing alliance relationships: key challenges in the early stages of collaboration. *R&D Management* 32 1: 11-22.

Kilinc, N. Ozturk, G. B. Yitmen, I. 2015. The changing role of client in driving innovation for design-build Projects: Stakeholders' Perspective. *Procedia Economics and Finance* 21: 279-287.

Kolb, B. 2008. Introduction to uses and methods of marketing research. SAGE research methods. Accessed May 23 2021. URL: http://methods.sagepub.com/book/marketing-research

Kuratko, D. F. Neubert, E. Marvel, R. M. 2021. Insights on the mentorship and coachability of enterpreneuers. Business Horizons 64 (2):199-209.

LaMorte, W. W. 2019. Diffusion of innovation theory. Accessed May 21 2021. URL: https://sphweb.bumc.bu.edu/otlt/MPH-Modules/SB/BehavioralChangeTheories/BehavioralChangeTheories4.html

Lithuanian Private Equity and Venture Capital Association (VCA LT). n.d. Trys sėkmės raktai startupams: mentorystė, teisinė bazė, komandos valdymas [Three keys to success for startups: mentoring, legal framework, team management]. Accessed May 23 2021. URL: https://vca.lt/naujiena/trys-sekmes-raktai-startupams-mentoryste-teisine-baze-komandos-valdymas/

LRT.lt. 2019. *Investuotojai: startuolių kūrėjai dažnai nežino, ko nori, kam reikalingas jų produktas* [Investors: Start-up developers often don't know what they want, who needs their product]. Accessed May 23 2021. URL: https://www.lrt.lt/naujienos/mokslas-ir-it/11/711572/investuotojai-startuoliu-kurejai-daznai-nezino-ko-nori-kam-reikalingas-ju-produktas

_________. 2020. Startuoliai Lietuvoje vienu didžiausių iššūkių ivardija finansavimo stoką [Startups in Lithuania name the lack of funding as one of the biggest challenges]. Accessed May 23 2021. URL: https://www.lrt.lt/naujienos/verslas/4/1143331/startuoliai-lietuvoje-vienu-is-didziausiu-issukiu-ivardija-finansavimo-stoka

Lu, Y. Khan, Z. A. Alvarez-Alvarado, M. S. Zhang, Y. Huang, Z. Imran, M. 2020. A critical review of sustainable energy policies for the promotion of renewable energy sources. *Sustainability* 12(12): 1-30.

Malysis, A. and Juozapaitienė, R. 2020. *Lietuvos inovacijų ekosistemos apžvalga* [Lithuanian innovation ecosystem overview]. Report prepared for Center for Goverment Strategic Analysis. Accessed May 24 2021. URL: https://www.stat.gov.lt/services-portlet/pub-edition-file?id=34380

Marketingo valdymas. n.d. Kompleksiniai marketingo paslaugų paketai [Complex marketing service packages]. Accessed May 23 2021. URL: https://marketingovaldymas.lt/marketingo-paslaugu-kainos/

Mazzucato, M. Semieniuk, G. 2017. Public financing of innovation: new questions. *Oxford Review of Economic Policy* 33: 24-48.

Metavallon. 2018. What does pre seed and seed investments mean?. Accessed May 20 2021. URL: https://metavallon.vc/blog/faq/pre-seed-seed/#:~:text=For%20us%2C%20Pre-Seed%20investment%20relates%20to%20the%20first,is%20at%20the%20early%20stages%20of%20its%20development.

Milčiuvienė. S, Užkurys. D. 2014. *Saulės energetikos plėtra: teisėti lūkesčiai ir visuomenės interesas* [Development of solar energy: legitimate expectations and public interest]. *Public Security and Public Order* 11: 116-130.

Minister of Economy and Innovation of Republic of Lithuania. 2018. Order on Priority 1 Promotion of research, experimental development and innovation of the operational programme for investments of European Union funds 2014-2020 01.2.1-MITA-T852 Description of the financing conditions for Inostartas projects No. 1 approval. 4-250.

Ministry of Energy of the Republic of Lithuania. 2018. *Nacionalinė energetinės nepriklausomybės strategija* [National energy independence strategy]. Accessed May 28 2021. URL: https://enmin.lrv.lt/uploads/enmin/documents/files/Nacionaline%20energetines%20nepriklausomybes%20strategija_2018_LT.pdf

_________.2019a. *Kuriama bandomoji reguliacinė aplinka energetikos inovacijoms* [A pilot regulatory environment for energy innovation is being developed]. Accessed May 24 2021. URL: https://enmin.lrv.lt/lt/naujienos/kuriama-bandomoji-reguliacine-aplinka-energetikos-inovacijoms

_________. 2020. *Veiksmų planas dėl Lietuvos energetikos srities inovacijų ekosistemos sustiprinimo* [Action Plan on Strengthening the Lithuanian Energy Innovation Ecosystem]. Accessed May 14 2021. URL: https://enmin.lrv.lt/en/news/lithuanias-energy-innovation-plan-approved-for-an-advanced-energy-sector

_________. 2020a. Lithuanias energy innovation plan approved for an advanced energy sector. Accessed May 20 2021. URL: https://enmin.lrv.lt/en/news/lithuanias-energy-innovation-plan-approved-for-an-advanced-energy-sector

_________. 2020b. *Pradeda veikti virtuali energetikos startuoliu ugdymo programa* [A virtual energy startup training program is launched]. Accessed May 23 2021. URL: https://enmin.lrv.lt/lt/naujienos/pradeda-veikti-virtuali-energetikos-startuoliu-ugdymo-programa

Ministry of Finance of the Republic of Lithuania. 2019. 2014-2020 m. *Europos Sąjungos fondųinvesticijų veiksmų programos tarpinis vertinimas* [Mid-term evaluation of the European Union Funds Investment Operational Program]. Accessed May 23 2021. URL: https://www.esinvesticijos.lt/lt/dokumentai//2014-2020-m-europos-sajungos-fondu-investiciju-veiksmu-programos-tarpinis-vertinimas

Mitev, N. Vaujany, F. Laniray, P. Bohas, A. Fabbri, J. 2018. Co-working Spaces, Collaborative Practices and Entrepreneurship. In: ed. Riemer, K. Schellhammer, S. Meinert, M. Collaboration in the Digital Age. Cham: Springer.

Mueller, J. 2021. Fiancial liquidity. Accessed May 20 2021. URL: https://www.investopedia.com/articles/basics/07/liquidity.asp#:~:text=Financial%20liquidity%20refers%20to%20how%20easily%20assets%20can,equipment%20are%20not%20as%20easily%20converted%20to%20cash.

New Philanthropy Capital (NPC). 2014. Creating your own theory of change: a practical guide. Accessed May 24 2021. URL: https://www.thinknpc.org/wp-content/uploads/2018/07/Creating-your-theory-of-change1.pdf

Novikova, A. Klinge, A. Hainaut, H. Cochran, I. Emmrich, J. 2019. Tracking investment into energy transition in Germany and France: a comparison of methodologies and selected results. Institute for Climate Protection, Energy and Mobility (IKEM) and the Institute for Climate Economics (I4CE), September, 2019.

Office of Gas and Electricity Markets (Ofgem). 2018. What is regulatory sandbox?. Accessed May 23 2021. URL: https://www.ofgem.gov.uk/system/files/docs/2018/09/what_is_a_regulatory_sandbox.pdf

Parliament of the Republic of Lithuania. 2011. The law of renewable energy or Republic of

Lithuania XI-1375. Accessed May 21 2021. URL: https://e-seimas.lrs.lt/portal/legalAct/lt/TAD/TAIS.398874

Ratkevičiūtė, J. Visockienė, I. Kerežis, D. 2020. *Lietuvos energetikos srities inovacijų ekosistemos sukūrimas* [Development of the Lithuanian energy sector innovation ecosystem]. Accessed May 24 2021. URL: https://enmin.lrv.lt/uploads/enmin/documents/files/Lietuvos%20energetikos%20srities%20inovacijų%20ekosistemos%20sukūrimas_2020(2).pdf

Reinholz, D. L. and Andrews, T. S. 2020. Change theory and theory of change: what's the difference anyway?. *International Journal of STEM Education* 7: 2-12.

Ries, E. 2009. Minimum viable product: a guide. Startup lessons learned. Accessed May 23 2021. URL: http://www.startuplessonslearned.com/2009/08/minimum-viable-product-guide.html#:~:text=First%2C%20a%20definition%3A%20the%20minimum,not%20about%20creating%20minimal%20products.

Schoen, J. Mason, T. W. William, A. Bunch, K. Bunch, R. M. 2005. The innovation cycle: a new model and case study for the invention to innovation process. *Engineering Management Journal* 17 (3): 3-10.

Sitra. n.d. Sitra Lab. Accessed May 24 2021. URL: https://www.sitra.fi/en/topics/sitra-lab/

Surana, K. Doblinger, C. Anandon, L. D. Hultman, N. 2020. Effect of technology complexity on the emergence and evolution of wind industry manufacturing locations along global value chains. *Nature Energy* 5: 811-821.

Teisė Pro. 2019. *Vyriausybė pritarė naujoms priemonėms, atsinaujinančios energetikos plėtrai ir energetikos inovacijų kūrimui skatinti* [The government has endorsed new measures to promote the development of renewable energy and energy innovation]. Accessed May 23 2021. URL: https://www.teise.pro/index.php/2019/10/31/vyriausybe-pritare-naujoms-priemonems-atsinaujinancios-energijos-pletrai-ir-energetikos-inovaciju-kurimui-skatinti/

Thomas, D. R. 2006. A general inductive approach for analysing qualitative evaluation data. *American Journal of Evaluation* 24(2): 237-246.

U.S. Department of Energy. n. d. Clean energy. Accessed May 20 2021. URL: https://www.energy.gov/science-innovation/clean-energy

United Nations Department of Economic and Social Affairs (UN Department of Economic and Social Affairs). 2020. Energy overview. Accessed May 14 2021. URL: https://sdgs.un.org/topics/energy

United Nations Development Group (UNDG). 2021. Theory of change: UNDAF Campanion guidance. Accessed May 23 2021. URL: https://unsdg.un.org/sites/default/files/UNDG-UNDAF-Companion-Pieces-7-Theory-of-Change.pdf

University Lab Partners (ULP University). 2020. Understanding pre-seed and seed funding for startups. Accessed May 23 2021. URL: https://www.universitylabpartners.org/blog/understanding-pre-seed-and-seed-fundings-for-startups

Visionary Analitics and Ministry of Economy and Innovation of the Republic of Lithuania. 2019.*2014-2020 m. Europos Sąjungos fondų investicijų veiksmų programos 1 prioriteto „Mokslinių tyrimų, ekspermentinės plėtros ir inovacijų skatinimas" poveikio vertinimo paslaugos"* [2014-2020 Impact assessment services for Priority 1 of the European Union Funds Investment Operational Program "Promotion of Research, Experimental Development and Innovation"]. Accessed May 24 2021. URL: https://www.esinvesticijos.lt/lt/dokumentai//2014-2020-m-europos-sajungos-fondu-investiciju-veiksmu-programos-prioriteto-moksliniu-tyrimu-eksperimentines-pletros-ir-inovaciju-skatinimas-poveikio-vertinimas

Visionary Analytics and the Ministry of Finance of the Republic of Lithuania. 2017. *Veiksmų programos uždavinių, skirtų moksliniams tyrimams, ekspermentinei plėtrai ir inovacijoms skatinti, įgyvendinomo pažangos vertinomo paslaugos: Galutinė vertinimo atasakita* [Progress evaluation services for the implementation of the objectives of the Operational Program to promote research, experimental development and innovation: Final evaluation report]. Accessed May 24 2021. URL: https://www.visionary.lt/wp-content/uploads/2017/06/FM-MTEPI-vertinimo-ataskaita-VIESINIMUI.pdf

Your Europe. 2021. CE marking. Accessed May 23 2021. URL: https://europa.eu/youreurope/business/product-requirements/labels-markings/ce-marking/index_en.htm

Zainal, Z. 2007. Case Study as a Research Method. *Jurnal Kemanusiaan* 5(1): 3-6.

Annex 1

Interviewee	Position	Organization	Group
1	CTO and Founder	*Urba* Start-up company founded in Vilnius, Lithuania, 2017.	Solar energy innovation startup founders from Lithuania
2	Head of Innovation	*Ulta* A state-controlled energy company in Vilnius, Lithuania.	Lithuania's solar energy innovation private financing experts
3	CEO and Co-founder	*Imra* Startup company founded in Kaunas, Lithuania, 2017. The company provides software engineering solutions to the development of PV solar energy systems.	Solar energy innovation startup founders from Lithuania
4	f. Vice-minister and current Advisor	*Lithuania's and EU's public institution*	Lithuania's solar energy innovation private financing experts
5	CEO	*Strata* Start-up company, launched in Vilnius, Lithuania, 2011. The company provides PV solar energy installation and maintenance services.	Solar energy innovation startup founders from Lithuania
6	CTO and Co-founder	*Ilko* Start-up company founded in Vilnius, Lithuania, 2017. The company provides internet of things (IoT) platform that provides monitoring for solar energy systems.	Solar energy innovation startup founders from Lithuania
7	Founder	*Saulė* Start-up company founded in Vilnius, Lithuania, 2013. The company provides the solar energy equipment manufacturing and maintenance for home.	Solar energy innovation startup founders from Lithuania
8	Head of Innovations and International Cooperation Group	*Lithuania's public institution*	Lithuania's solar energy innovation public financing experts
9	Manager Photovoltaic	*EU's research institution*	EU solar energy innovation financing experts

	Technology and Energy Systems		
	Professor Digital Photovoltaics	*University*	
	Joint Program Coordinator Photovoltaics	*EU's research institution*	
	Editor-in-Chief	*Private company*	
10	Acting director	*Lithuania's public institution*	Lithuania's solar energy innovation private financing experts
11	Energy Economist	*Lithuania's research institution*	Other expert
12	Policy Officer at DG Research & Innovation (clean energy)	*European public governance institution*	EU solar energy innovation financing experts
13	Chief advisor	*Lithuania's public institution*	Lithuania's solar energy innovation public financing experts
14	Private Investor	*INVEST*	Lithuania's solar energy innovation private financing
15	Advisor	*European organisation working of solar energy innovation financing*	EU solar energy innovation financing experts
16	Independent Investment Advisor	-	Lithuania's solar energy innovation private financing
17	Program Officer	*European innovation and research institution*	EU solar energy innovation financing experts

Annex 2

Group of interviewees	Questions
Common questions	How would you define the solar energy innovation? What are the gaps and opportunities of solar energy innovation? How do you see the role of government in encouraging the solar energy innovation?
Lithuania’s solar energy innovation public financing experts	What is the public role in developing the solar energy innovation in Lithuania? What are the current programs to move solar energy innovation to a good direction? Based on your opinion, the public financing help solar energy innovation companies to move from the research stage to commercialization (overcome the “valley of death”)? Based on your perspective, how can public finance encourage the development of solar energy innovation (R&D stage particularly) in the future? Do you see the European Green Deal as having a place in this at all? If so, why, if not, why not? What lessons are learned from the financing of solar energy R&D innovation stage companies from 2016 to 2020? From your perspective, how can the public financing of solar energy R&D stage innovation companies be improved?
Lithuania’s solar energy innovation private financing experts	How do you assess the role of public sector finances in promoting solar energy innovations in Lithuania? Is this role fulfilled? How can the authorities improve the financing mechanism for early-stage solar energy? What would be your recommendations? What could the Lithuanian authorities do to better fund solar start-ups following other countries' examples? What are the lessons learned from the financing of solar energy innovation in 2016-2020?

EU solar energy innovation financing experts	How can public financing (EU and member states national) help solar energy innovation companies (startup stage) to overcome “the valley of death” (difficulty of covering the negative cash flow in the early stages of a startup)? Based on your perspective, how can public finance encourage the development of solar energy innovation (R&D stage particularly) in the future? Do you see the European Green Deal as having a place in this at all? If so, why, if not, why not? How can public financing of solar energy innovation in Lithuania be improved based on what was done well in other EU member states?
Solar energy innovation startup founders from Lithuania	What was the biggest challenges that you faced before your company received the financial support from private and public sectors? How do you see the role of public finance in developing the solar energy innovation in Lithuania? How did the public financing helped you to develop your product in comparison to the private financing? How did public financing helped you to overcome the “valley of death”? Is the public support effective? How to improve it? What would be your recommendations for the government? How can solar energy innovation financing mechanism be improved?

Outside perspective	In your opinion, how does public finance help solar innovation companies (in the R&D stage) to move from the research phase to commercialization (overcoming the "death valley")? From your perspective, how can public finances promote the development of solar energy innovation (especially the R&D phase) in the future? Do you see that the European Green Course can help? If so, why, if not, why not? What are the lessons learned from financing solar R&D start-ups from 2016 to 2020? How do you think public funding for start-ups for solar R&D innovation can be improved to help them achieve commercialization? What would be your recommendations to the current authorities?