Explaining residential solar energy generation across municipalities

A quantitative study of the diffusion of residential solar photovoltaic panels across Dutch municipalities in 2015-2017

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01-07-2020

Study programme: Management, Society & Technology

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Word count: 11.957

Abstract

This research investigates the extent to which political and societal variables influence the diffusion of residential photovoltaic systems across municipalities in the Netherlands. Various secondary databases were consulted to obtain relevant data for these variables for as many municipalities as possible, which are quantitatively analysed in multiple regression analyses. The research question answered in this research is ''*What are factors that explain differences in residential solar energy generation between Dutch municipalities?''*. Six hypotheses and six sub-hypotheses were formulated, which all assume a positive relationship amongst societal and political variables or on their effect on diffusion of residential photovoltaic systems across municipalities. The research concludes that procured subsidies and the presence of energy cooperatives in a municipality positively influence the diffusion of residential photovoltaic systems in Dutch municipalities. The presence of energy cooperatives is positively influenced by the education level of individuals, as well as the share of seats a green political parties occupies in the Municipal Council and the presence of at least one Alderman who represents a green political party.

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List of Abbreviations

PV: Photovoltaic
Council M&A: Council of Mayor and Aldermen (*College van Burgemeester en Wethouders)*
D66: Democraten 66 (Democrats 66)
PvdD: Partij voor de dieren (Party for the animals)
GL: GroenLinks (Green Left)

1. Introduction

In 2018, the share of renewable energy sources in the total energy consumption in the EU was 18,9%, on its way to the objective to be the world's first climate-neutral continent by 2050. Of all the EU member states, the Netherlands scored the lowest percentage in terms of energy consumption from renewable energy sources (Eurostat, 2020). In 2019, the share a share of renewable energy sources was only 8.6 percent in (Rotman, 2019). In the same year, the Dutch government reached the Climate agreement (*or Klimaatakkoord*) with over 100 involved stakeholders. One of its main goals is to produce 49% less CO2 in the Netherlands compared to CO2 production in the Netherlands in 1990 (Rijksoverheid, 2020). One of the main points of the Climate agreement is for 21 to 23 gigawatt peak solar panels (solar PV or solar photovoltaic) to be deployed by 2030 (Solar Magazine, 2018.) This helps the Netherlands to decrease its negative climate impact as a cause of their energy consumption, as large-scale PV systems provide significant environmental benefits and advantages when compared to conventional non-renewable energy sources (Castillo, Batista e Silva and Lavalle, 2016).

In 2017, 16,67 billion kW energy from renewable energy source was produced in the Netherlands, of which 2.208 billion kW or 13,24% was solar energy (CBS, 2020). The total amount of deployed solar panels in kW was 4.574 million kW, of which 1.671 million or 36,53% was deployed on residences (CBS, 2019). Based on preliminary data, solar energy production in 2019 skyrocketed to 5.189 billion kW or 23,87% of all renewable energy sources (CBS, 2020). Despite the recent, relatively steady overall increase of produced solar energy in the Netherlands, immense differences between municipalities exist in terms of the amount of solar energy that is generated through residential solar PV installations, as can be seen in figure 1 (CBS, 2019).

With the exception of a few articles, not a lot is published about explaining regional differences in residential PV uptake in the Dutch context, but numerous articles which investigate PV adoption rates outside of the Dutch context are published. It is scientifically relevant to find out whether or not these results are replicable in the Netherlands. This research aims to fill that specific research void of explaining local differences in terms of residential solar panel adoption in the Netherlands, as well as making a contribution to the existing body of knowledge about residential solar PV adoption. This research zooms in on six potential factors identified in the literature that can help to explain the dependent variable, residential PV adoption rates. These factors are categorized as either *political* or *societal* factors. The *political* factors include procured subsidies for residential solar PV adoption, Municipal Council political party composition and Council M&A political party composition. The *societal* factors include the presence of local energy cooperatives, household income level and education level of individuals. Figure 1 illustrates that large variations exist in Dutch municipalities in regards to these variables. It includes the scores of municipalities with the highest and lowest scores on the researched variables. All these differences between Dutch municipalities can help to explain the diffusion of municipal residential PV. This research aims to determine the extent to which this is the case.

Figure 1: Differences between municipalities	*Highest score*	*Municipalities*	*Lowest scores*	*Municipalities*
Residential PV	17.795 kW 14.926 kW 14.317 kW	Almere Zwijndrecht Amsterdam	99 kW 99 kW 155 kW	Vlieland Aalburg Rozendaal
Residential PV per capita	0.393 kW 0.366 kW 0.336 kW	Loppersum Slochteren Ten Boer	0.015 kW 0.0169 kW 0.019 kW	Rotterdam Amsterdam Schiedam
Subsidies per capita	7.28 kW 7.04 kW 7.04 kW	Losser Borger-Odoorn Nuth	0.048 kW 0.061 kW 0.08 kW	Sliedrecht Vianen Barendrecht
High Income level	48.6% 43.37% 37.7%	Rozendaal Bloemendaal Laren (NH.)	10.03% 10.2% 10.3%	Heerlen, Pekela, Groningen
High education level	60,21% 53,19% 51,45%	Utrecht Amsterdam Leiden	16,67%	Nine municipalities
Energy cooperatives	5.67 5 4.67	Súdwest-Fryslân Tilburg Amsterdam	0	Many municipalities
Green parties Municipal Council	51.11% 43.59% 46.67%	Utrecht Amsterdam Leiden	0	Many municipalities
Green parties M&A Council	1	148 municipalities	0	240 municipalities

Figure 1: Highest and lowest scores by municipalities on all variables included in this research

Besides the focus of this research on the relationship of the dependent variable, residential PV production, vis-à-vis the independent variables, this research will zoom in on some relationships amongst independent variables. Separate sub-hypotheses are highlighted in the theoretical framework that are constructed based on relationships amongst independent variables. These relationships are potentially important when explaining the original relationship of the dependent variables vis-à-vis the independent variables. Next to this, population size of municipalities is used as a controlling variable in explaining the bivariate relationships of the dependent variable and the independent variables. Various secondary databases are consulted to be able to arrive at a quantitative estimation of the strength and direction of the aforementioned relationships.

A better understanding of the variations in municipal solar PV diffusion could help local Dutch policy makers to encourage residential PV uptake in their respective areas. This fact is where this research draws its societal relevance from. On some variables, like education level, policy makers cannot have a large influence, but other variables, like energy cooperatives, can certainly be influenced by Dutch local policy makers. It is especially necessary for Dutch local policy makers to increase the PV uptake in their municipalities, because the Netherlands is scoring the lowest of all EU Member States in the share of produced energy by renewable energy sources (Eurostat, 2020). The scientific relevance of this research draws from the fact current literature points to many different, diverging factors that explain local distribution of solar PV. No straightforward explanation for why some regions adopt large amounts of solar panels and some do not is available, consensus amongst researchers is not explicitly vivid. To address all of this and to estimate whether or not similar conclusions can be drawn from the Dutch context, the research question that will be answered in this research is ''*What are factors that explain differences in residential solar energy generation between Dutch municipalities?*''

2. Theoretical Framework

This chapter outlines the relevant literature on the subject of (residential) PV deployment for all variables. For each variable, a literature review is included and the expectations for the analysis based on this literature. At the end of each section one or more (sub-)hypotheses are presented, which are based on these expectations. The hypotheses include relationships between residential PV deployment and the independent variables, but also amongst independent variables.

2.1. Political variables

2.1.1. Subsidies and Policies reducing investment costs

For many households, solar PV panels are an expensive investment. Financial considerations can be a key factor in the decision-making process of households on whether or not to purchase solar PV panels (Jager, 2006). Financial incentives can help to make the purchasing of solar PV panels more attractive. Examples of such financial incentives are tax returns for the consumption of green energy or governmental subsidies for the adoption of solar PV panels. Ozkan, Yildirim and Connor (2015) summarized motivations and barriers associated with adopting microgeneration found in the literature, which includes solar PV. Financially, two motivations were found for microgeneration uptake: saving or earning money from lower fuel bills and government incentives, or increasing the value of the home. The financial barriers are costs being too high to buy/install and being unable to earn or save enough money.

Zhang, Song and Hamori (2011) found that installation costs have a significant negative effect on PV system adoption. Bauner and Crago (2015) find that the discounted value of benefits from solar PV needs to exceed installation costs by 60% for an investment to occur. These findings coincide with the financial barriers of installation costs being too high and the inability of people to earn or save enough money. In addition, Yi and Li (2014) found that U.S. cities with local financial incentives deploy 69% more solar PV capacities than cities without. Next to that, Zhang, Song and Hamori (2011) and Kwan (2012) identified that (regional) government financial incentives are a significant explanatory factor for the spatial distribution of solar PV. Additionally, Dharshing (2017) concludes that differences in economic incentives have an influence on spatial patterns of residential PV systems across Germany. Balcombe, Rigby and Azapagic (2013) discovered that, despite significant governmental financial efforts to stimulate the adoption of microgeneration in the UK, consumer uptake remained low, because the policies did not sufficiently address the most significant barrier: capital costs. These costs are comparable to installation costs and it would make sense that consumer uptake in the UK remained low, if their financial incentives did not sufficiently address capital costs of microgeneration technologies, as the literature suggests the height of installation costs plays a large role in the decision of consumers to purchase solar PV panels.

National governments set goals of having a certain share of the nationally consumed energy to be generated through renewable energy sources. To reach these goals, governments can incentivize consumers to switch to renewable energy sources, such as solar PV panels. Since 2008, the Stimulation Sustainable Energy (Stimulering Duurzame Energie, or SDE) was introduced by the Dutch Ministry of Economic Affairs and Climate. This subsidy arrangement provided for six different types of renewable energy, including solar energy, and was available for companies, (non-profit) institutions and citizens/households (Beter Duurzaam, 2020). Since 2011 this subsidy arrangement became SDE+. Since its introduction, no universal subsidy for private individuals or households is provided by the Dutch government on a national level. As time progressed, municipalities have withdrawn from providing subsidies for individuals and households more and more, partly because solar panels currently are profitable enough without subsidies (Milieu Centraal, 2020).

Subsidies can decrease the aforementioned barriers that households experience, by alleviating the inability of households to earn or save enough money to adopt solar PV panels, because subsidies can greatly reduce the height of the initial costs of solar PV panels. This lower price can result in more households having the ability to save up enough money to reach that particular price, whereas they were unable to save up enough money before subsidies were provided. Additionally, solar PV subsidies have the potential to contribute to increasing the value of homes. When households adopt solar PV panels, their home value will most likely increase, because the saved annual electricity costs as a result of the generated solar PV energy form an incentive for potential home buyers to pay a larger sum of money when purchasing the respective home. This increased home value can help to motivate households to purchase solar PV panels for their homes.

The most recent available data of residential PV subsidies of all municipalities in the Netherlands is the SDE subsidy scheme from the years 2008 until 2010 (RVO, 2019). Within this database, differences exist between municipalities in terms of whether or not subsidies were provided in the first place and the average height of the provided subsidies. In this research is hypothesized that the more subsidies were provided for residential solar PV panels, the more residential solar energy is generated in municipalities between. This is hypothesized based on the mechanisms described above. Therefore, the first hypothesis is established:

H1: The more SDE subsidies towards residential solar PV panels are procured in a municipality between 2008-2010, the more residential solar energy is generated in a municipality between 2015 and 2017.

2.1.2. Municipal Council Political party composition

The renewable energy transition is ultimately a political process and struggle, as efforts to shift from fossil fuels to renewables will not happen without destabilizing and confronting dominant systems of energy power (Burke and Stephens, 2018). This process happens on various levels, including the local level. The general electorate of green parties are seen as issue-based, 'activist' voters, where young, nonreligious, female, urban and educated people are more likely to support green parties throughout Europe (Delwit and Close, 2016). In addition, Cruz (2017) found that political party affiliation has a substantial association with environmental concern. This means that people who vote for green local parties might be more concerned with the environment and because of that be more likely to adopt solar PV panels.

Palm (2016) discovered there was no consistency in left-right political orientation of local governments when researching its effect on residential PV adoption rates between the studied municipalities in Sweden. Dharshing (2017) proxied environmental attitude as a calculation of the share of green voters in German counties. The relationship between environmental attitude and regional PV uptake was unclear, since some of the statistical analyses he ran showed environmental attitude to have a significant positive effect on regional PV uptake, whereas other statistical tests came to insignificant positive effects. Next to that, Kwan (2012) found evidence in the U.S. that registered Democrats have higher residential solar PV shares than Republicans. Only Kwan (2012) found evidence that political affiliation plays a significant role, but the Dutch setting differs from the Swedish, German, or American one. This makes researching the Dutch context scientifically relevant.

In the Netherlands, the Municipal Council is elected every four years by citizens of municipalities and the Council has between nine and 45 representatives in it (Nederlandse Vereniging voor Raadsleden, 2020). Seats are distributed in such a way that if a party gets ten percent of the vote, they will get around ten percent of the seats. Municipal Councils in the Netherlands are quite heterogenous; some Councils constitute many representatives from green political parties, but most Councils do not. Broadly speaking three green political parties exist in the Netherlands that play a role in local politics: D66, GL and PvdD. In the Netherlands the Council M&A forms the executive board of a municipality (Nederlandse Vereniging voor Raadsleden, 2020). Once the Municipal Council is elected, its first important task is to negotiate and agree on the composition of the Council M&A.

Green parties are parties that focus on ecologist or green ideologist policy plans or other types of action that contribute to a more sustainable environment (Little, 2014). Green parties can take action in various ways. An example of such an action is providing subsidies for residential solar PV panels, or increasing the exposure of subsidy schemes that already exist. Following from this logic, a higher share of green political parties that partake in local politics would result in more provided subsidies for residential solar PV panels. This, in turn, would lead to more produced residential solar energy as well. In this research it is also hypothesized that when more seats are occupied by green parties in Dutch Municipal Councils, it would lead to more solar PV uptake in a municipality. This is because the electorate of green parties are hypothesized to care more about the environment, which means they are more likely to adopt residential PV, as this helps to make society more sustainable. In addition, pro-environmental households might perceive the (financial) barriers of solar PV panels as less problematic. These households might be more willing to spend their limited resources on things such as solar PV panels, precisely because of their environmental concern. The sub-hypothesis and hypothesis for this variable are:

Hypothesis 2a: The more seats are occupied by green political parties within the Municipal Council in 2014-2018, the more SDE subsidies are procured within a municipality between 2008-2010.

Hypothesis 2b: The more seats are occupied by green parties within the Municipal Council in 2014-2018, the more residential solar energy between 2015-2017 is generated in a municipality.

2.1.3. Council M&A political party composition

According to Talshir (2002), the rise in ecological awareness that supported the development of the idea that natural resources are finite was instrumental to the emergence of green political parties, which happened around the 1980s in Europe (van Haute, 2016). Talshir (2002) argues that ecological issues need social visions and political plans in order to be implemented. These plans need to be prioritized over other social or political visions in order to be materialized. The particular beliefs that contribute to solving ecological issues are largely shared by green political parties. Green political parties are relatively homogenous in the sense that their platform by and large revolves around ecological issues and environmental concerns (Talshir, 2002; Little, 2014; Carter, 2013; Ennser, 2010; Spoon, 2009). This notion is often referred to as ‘ecologism’ or ‘green ideology’ (Little, 2014). This green ideology forms a large building block of the party programmes and policy papers created by green political parties. Next to this, the green political party family is characterized as a force that emphasizes the importance of typical left-wing values, such as solidarity, equality and fairness (Carter, 2013; Ennser, 2012).

Throughout Europe, green political parties are mostly opposition parties that have not been a coalition partner, but there are certainly cases where green parties participated in the coalition (van Haute, 2016). Councils of M&A are comparable to parliamentary coalitions, but on the Dutch local level. These are the bodies that draft and execute political policy plans, the bodies that exercise political power. Despite the findings of Palm (2016) and Dharshing (2017) as described under the previous hypothesis, it would be expected that if a green party is represented in the Council of M&A,

a larger emphasis on ecologist and green ideologist policies would be placed. Increasing the amount of residential solar PV panels is an example of a goal of an ecologist policy. This increased emphasis could result in an increase in provided financial resources to combat climate change, such as providing subsidies or tax returns for residential solar PV panels.

A municipality is represented by between two and eleven Aldermen (VNG, 2020). According to data from VNG of the year 2019, both D66 and GL managed to obtain around seven percent of all Dutch Aldermen, which roughly adds up to fourteen percent of all Aldermen (VNG, 2020). Municipal executive governments can change existing rules to make PV adoption easier. The municipality of Amsterdam, as an example, changed laws which resulted in a significant increase in space for solar energy (Berends, de Jong and Wagter, 2015). Next to that, municipal executive governments can provide information about solar PV panels to citizens and companies, facilitate citizen initiatives and energy cooperatives and use the roofs of local governmental buildings to place solar PV panels there (Berends, de Jong and Wagter, 2015). This means it is likely that in municipalities where green parties are a part of the Council of M&A, a larger amount of produced residential solar PV panels can be found compared to municipalities where green parties are not a part of the Council of M&A. Similar to the Municipal Council party composition hypotheses, it is hypothesized that when at least one green party is represented in the local executive government, more subsidies are procured in that particular municipality. This results in the following hypotheses:

Hypothesis 3a: In municipalities where one or more green parties are represented in the local executive government in 2014-2018, more SDE subsidies are procured in 2008-2010 compared to municipalities where no green political party is represented in the local executive government in 2014-2018.

Hypothesis 3b: In municipalities where one or more green parties are represented in the local executive government in 2014-2018, more residential solar energy is generated in 2015-2017 compared to municipalities where no green political party is represented in the local executive government in 2014-2018.

2.2. Societal variables

2.2.1. Local energy cooperatives

Groups of citizens are united in the Netherlands in local energy cooperatives (Energiecoöperaties). Energy cooperatives are initiatives of citizens who together want to work on achieving sustainable local energy (Greenchoice, 2020). Citizens can for instance invest in the generation of wind or solar energy, or get help with finding available locations for solar panels because they do not have the capital to purchase solar panels for their home. According to empirical research performed by van der Veen (2017), energy cooperatives form a niche within the Dutch energy transition, as a local and sustainable counterpart of the fossil regimes. She identifies governmental policy as an important external factor for the development of energy cooperatives. In addition, energy cooperatives fulfill three potential roles: as energy producer, as initiator of new experiments and as mediator between parties or as coordinator of the rules of the (local) energy system (van der Veen, 2017).

The literature confirms the idea that local active organizations that promote or bring about solar initiatives leads to more residential solar PV, be it regionally or nationally. Palm (2016) identified local organizations promoting PV as an important explanatory factor for the high amount of local PV installations. Palm (2016) also refers to the work of Noll et al., who found similar results. Schaffer and Brun (2015) argue local pro-solar movements are a potential source of regional spillover effects. Next to that, Dewald and Truffer (2012) found that local pro-solar initiatives create knowledge externalities, as it has the ability to inspire or help develop such initiatives in neighboring regions. Schaffer and Brun (2015) point to the work of Backhaus and Hodson et al., who discovered that intermediary organizations play a crucial role in bringing about the energy transition.

It could be expected that the presence of local organizations that produce, initiate or mediate (solar) initiatives would lead to more residential solar PV in a region. Specifically Dutch energy cooperatives can increase the exposure of solar PV panels because of their potential role as producer, initiator or mediator. Thus, more people would get acquainted with the economic and environmental benefits of adopting solar PV panels, which in turn could lead to an increased willingness of households to purchase solar PV panels for their homes. As an example, people who might start off as just investors in a solar park project because it is lucrative learn more about the environmental and economic benefits of solar energy. Because of that, they are more likely to purchase solar PV panels for their own homes, but they are also more likely to share their knowledge with their local acquaintances, who might in turn also adopt solar PV panels. The literature strongly points to the existence of a significant relationship between local organizations that promote or bring about solar initiatives and residential solar PV. Because of that, and the characteristics of cooperatives as described by van der Veen (2017), it is assumed in this research that the more local energy cooperatives and production cooperatives are active in a municipality in 2015-2017, the higher the amount of produced residential solar PV in 2015-2017 would be.

The examples of actions municipalities or political parties can take in regards to enhancing residential solar PV as described by Berends, De Jong and Wagter (2015) includes facilitating citizen initiatives and energy cooperatives. Because of that, and because of the description of van der Veen (2017) that governmental policy is an important external factor for the development of energy cooperatives, it is expected that when the share of green political parties in the Municipal Council increases and/or a green political party is represented in the local executive government, a more facilitative role of the local governmental bodies is taken towards energy cooperatives. This research hypothesizes that a higher share of green political parties in Municipal Councils in, as well as the presence of one or more Aldermen who represents a green political party, would increase the average amount of energy cooperatives in.

The hypotheses for the third variable entail:

Hypothesis 4a: : The more seats are occupied by green parties within the Municipal Council in 2014-2018, the more local energy cooperatives are active in that municipality in 2015-2017.

Hypothesis 4b: In municipalities where one or more green parties are represented in the local executive government in 2014-2018, more local energy cooperatives are active in 2015-2017 compared to municipalities where no green party is represented in the local executive government in 2014-2018.

Hypothesis 4c: The more local energy cooperatives are active in a municipality in 2015-2017, the more residential solar energy is generated in a municipality in 2015-2017.

2.2.2. Income level

Income influences the spending power and consumption behaviour of individuals and households respectively. In general, having a higher income increases your spending power, as having a high income in theory means you have more money at your disposal to put aside for future purchases, assuming your expenses do not increase accordingly. A higher spending power of households, as a result of a higher average income, could mean the barrier of the initial costs being too high, as described under hypothesis 1, decreases and households indeed are more likely to adopt solar PV panels.

Berends, de Jong and Wagter (2015) found that in Dutch municipalities where the level of average income is slightly above average, the largest amount of solar energy per capita is generated. Dharshing (2017) and Schaffer and Brun (2015) found income of individuals to have a significant effect on distribution of PV deployment. Dharshing (2017) particularly found that population shares of individuals with high income lead to higher numbers of regional residential PV uptake. Kwan (2012) found the same results, but for households instead of individuals. Kwan (2012) also makes a reference to articles of Lam and Chang and Lee, who linked higher median household incomes with an increase in solar technology adoption. However, Balta-Ozkan, Yildirim and Connor (2015) and Palm (2016) find no significant relationship between income at the individual level and regional PV uptake. The data that is used in this research to check for the significance of the relationship between income and municipal solar PV uptake will focus on the household level, rather than the individual level. Household income differs from individual income, but most individuals live in a household, so it is expected that the income of individuals has a large influence on the income at the household level, and there will likely be a strong correlation. This would mean that the findings of aforementioned researchers are by and large applicable to the relationship between residential income and residential PV uptake, rather than only between individual income and residential PV uptake.

For this variable, there is not as much academic consensus on the reliability of the relationship between household/individual income and regional residential PV uptake. Yet, it is hypothesized in this research that in municipalities with a higher share of high household incomes, generally more solar PV panels are adopted. This is primarily because of the increased spending power of households that comes along with an increased average household income, which in turn reduces the barrier of high initial costs. A similar argument can be made for the emergence or presence of energy cooperatives instead of residential solar PV. These cooperatives are citizen initiatives, in which citizens often invest money to generate sustainably produced energy. Having a higher income enables households to make this type of investment, as a high income can alleviate the barriers of high initial costs. The hypotheses for the energy cooperatives variable are:

Hypothesis 5a: The higher the share of households in a municipality is that possesses an average high income in 2014-2016, the more local energy cooperatives are active in a municipality in 2015-2017.

Hypothesis 5b: The higher the share of households in a municipality is that possesses an average high income in 2014-2016, the more residential solar energy is generated in a municipality in 2015-2017.

2.2.3. Education level

Human capital refers to 'the knowledge, skills, and other personal characteristics embodied in people that helps them to be productive' (OECD, 2020). Human capital is something that is greatly enhanced by education, as to get educated is related to strengthening knowledge and skills, which may help persons to be more productive in their career. Traditionally there is a strong relationship between education and income (Wolla and Sullivan, 2017). This has to do a lot with obtaining relevant skills and knowledge which helps people to pursue more high-paying careers. Generally highly educated people have more relevant skills that can be applied on the work floor, which means they are more likely to be hired and thus the unemployment rate is lower, which contributes to an overall average higher income for highly educated people or households.

Dharshing (2017) finds a significant relationship between population shares with high education levels and regional residential PV uptake. Dharshing (2017) refers to articles of Davidson et al., Sigrin et al., and Sardianou and Genoudi, who all found a positive association between education level and PV uptake. Balta-Ozkan, Yildirim and Connor (2015) also found that the education level of households affects PV uptake in a region. In their article, they mention that Jager and Keirstead wrote articles in the years 2006 and 2007 respectively, where they interviewed early PV adopters. They found that early adopters were better educated than non-adopters. Kwan (2012) found that the proportion of the population in the U.S with at minimum a college education is a statistically significant factor explaining spatial distribution of residential solar PV. In his article, Kwan (2012) makes a reference to an article of Kellstadt et al., who discovered that consumers with at minimum a college education are more likely to adopt new technologies. Yi and Li (2014), on the other hand, noticed the percentage of citizens with a bachelor's degree or higher is insignificant when explaining the diffusion of solar PV installations in U.S. cities. Those findings are the only available findings where the conclusion is drawn that the relationship between education level and PV uptake is insignificant.

It would make sense that the relationship appears to be significant in most studies, as there are various possible explanations as to why higher educated populations adopt more solar PV panels. It can be expected that households with an average higher level of education are more aware of the benefits, or simply the mere existence, of solar PV panels. It could be that some fairly rich yet not highly educated households have the capital to invest in solar PV panels, but they are unaware that this will save them costs in the long run or that it contributes to the making of a more sustainable planet. Next to this, as explained before, a higher income could lead to a higher spending power, which can decrease the barrier of costs being too high to adopt solar PV panels.

Additionally, it can be expected that in municipalities with a relatively highly educated population, more energy cooperatives exist. Creating and managing energy cooperatives requires a certain set of knowledge and skills, which are related to the human capital of people. Without being aware of what an energy cooperative can bring about, it is far less likely to emerge at all, and having a high share of highly educated people in a municipality means there can be more of this awareness that leads to the presence of more energy cooperatives. The hypotheses of the final variable are:

Hypothesis 5a: The higher the average share of highly educated people in a municipality, the more local energy cooperatives are active in a municipality in 2015-2017.

Hypothesis 5b: The higher the average share of highly educated people in a municipality in 2014-2016, the more residential solar energy is generated in a municipality in 2015-2016.

Figure 1 displays the assumed direction of the relationships amongst independent variables, as drawn from the sub-hypothesis, as well as the assumed direction of the relationships between independent variables and the dependent variable, residential solar energy generation in Dutch municipalities. The green line resembles an assumed positive relationship, which entails that all assumed relationships from the (sub-)hypotheses are positive. A similar figure is presented at the end of the Analysis chapter, which displays the true relationships amongst all variables based on the performed analyses.

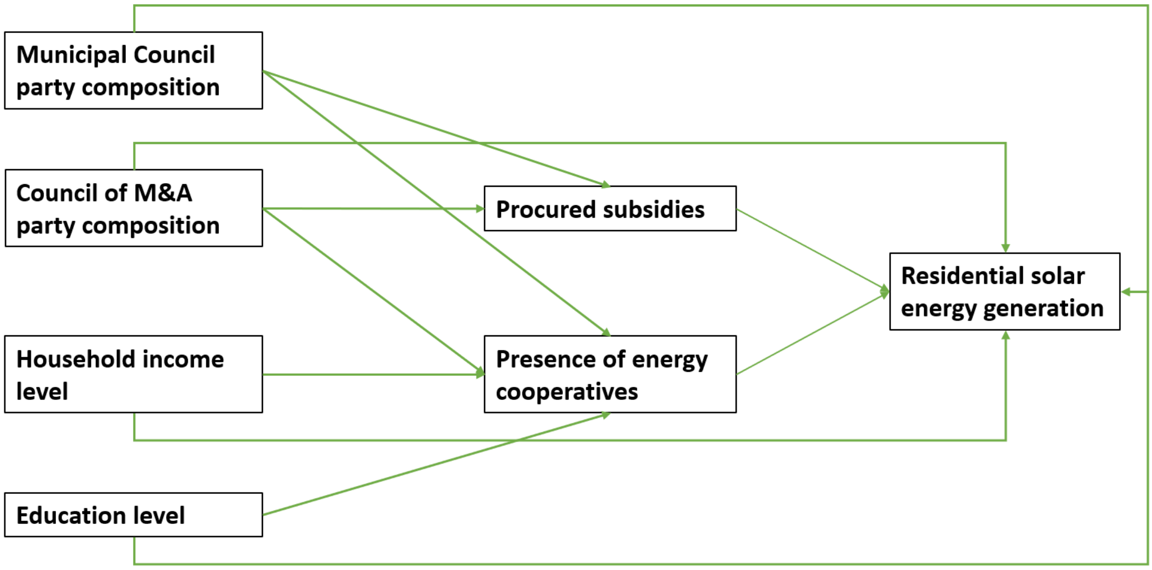

Figure 2: Causal diagram based on (sub-)hypotheses

3. Data

All data used in this research were collected via public online secondary sources, mostly comprising databases of Statistics Netherlands (*Centraal Bureau voor de Statistiek,* or CBS), which is a Dutch agency that keeps track of and regularly updates various statistics regarding the Dutch population. For the purpose of this research, one large database is created containing data of all variables used in the research. With all the data a quantitative analysis is performed. The units of analysis are Dutch municipalities that existed in 2017, with N=388. After 2017, several municipalities were disestablished and merged with other municipalities, creating either entirely new municipalities, or enlarging already existing municipalities. Various datasets of variables comprised names of cities or villages, rather than of municipalities itself. These locations were coded into municipalities, using a database which consists of all Dutch cities and villages and municipalities, which was last updated in October 2019. (Metapos, 2019). Municipalities that arose after 2017 were coded into the municipalities they were a part of prior to 2017. Another dataset of Statistics Netherlands was used to check for the amount of residents per municipality in 2017 (CBS, 2020). These data are used for some variables, where a calculation for that variable per capita is made. This chapter functions as an explanation on how and where data were collected, how it is operationalized and how it is coded into the database of the variables of this research. In addition, a table with descriptive statistics of the dependent variable and independent variables is provided.

3.1. Residential solar energy

The dependent variable of this research is residential solar energy per Dutch municipality. Data from Statistics Netherlands on solar energy is published for the years 2012 to 2017 (CBS, 2019). Within this particular dataset one has the option to distinguish between the number of PV installations per municipality or the amount of solar energy in kW. Additionally, the entire dataset comprises data on solar energy produced for economic activities and for residences. The data can be filtered on various geographical levels, including the municipal level. Data of the amount of produced residential solar energy in kW is used rather than the number of installations. This gives a more precise representation of the generated residential solar energy and the numbers are more easily comparable than the number of installations. Additionally, data about economic activities are excluded and the data is taken at the municipal level.

Where possible, data from the years 2015, 2016 and 2017 have been used to arrive at the average yearly production of residential solar energy, where N=388. For some municipalities, data of one or more of those years were missing. If this were the case, data from 2014 were added to arrive at the average produced residential solar energy. Only a few cases exist where the average is of two or less years combined. Data of average residential solar energy is divided by the number of residents per municipality in 2017, to arrive at an average of yearly generated residential solar energy in kW per capita per municipality.

Figure 3 shows that data of all years is present for 388 municipalities. The average yearly produced residential solar energy per municipality shifted from 1693,08 kW in 2014 to 4294,38 kW in 2017, which is an increase of over 153% in the timespan of just four years. The calculated average yearly produced residential solar energy per municipality is at 3353,73 kW. The lowest amount of average yearly produced residential solar energy from 2015 to 2017 in a municipality is 54,33 kW and the highest amount is 15496,33.

3.2. Independent variables

3.2.1. SDE Subsidized solar energy

Because no database of governmental subsidies after 2011 could be consulted, the database of the Netherlands Enterprise Agency (*Rijksdienst voor Ondernemend Nederland, or RVO*) of SDE subsidies was consulted. SDE Subsidies were provided until 2011 and included inter alia subsidies for residential solar energy (RVO, 2019). This enormous database comprises data of all different types of sustainably produced energy, from the years of 2008 until 2016. It also comprises data of subsidies aimed at companies or organizations. Due to privacy reasons, names that could be traced back to persons were not included in the database. The database consists of various types of data. The relevant data are the location and solar panel power in mW.

The solar panel power was changed to power in kW, to make it comparable to the dependent variable. All subsidies provided to a company or an organization were excluded, so only the anonymous entities remained available. Of these anonymous entities is assumed the subsidies pertain to households or individual residents All subsidies that were procured for solar PV panels that generate more than 0.01 mW, or 10 kW, were excluded. Solar panels amount to around 300 Wattpeak, which means over thirty solar panels would have to be placed on a roof of a household to reach 0.01 mW (Van der Wilt, 2019). This seems to be nearly impossible, so it is somewhat safe to assume subsidies provided over 0.01 mW do not belong to households. After excluding all these subsidies, over 7000 relevant subsidies remained in the dataset. Data about the Dutch population of Statistics Netherlands were used to calculate the average subsidized solar power in kW per capita per municipality. The data about subsidized solar power in kW per capita are used in the analysis of this research.

3.2.2. Municipal Council Political party composition

Data of the Municipal Council elections of 2014 were taken from the database of Kiesraad with N=374 (Kiesraad, 2020). In this database the percentage of seats occupied by green political parties on the basis of the results of the 2014 Municipal Council elections were found. The selected parties are D66, GL and PvdD. Some locally established political parties that do not operate on a national scale identify themselves as a green political party. These parties are not included in the dataset. Locally established parties are too diverse and it would not be feasible to include them in this research. These parties are not excluded from the denominator when the calculation was made of the share of green parties on the overall seats in a municipality.

Some local parties are combinations of political parties. If combinations of parties comprised at least one of the green parties, they are included as a green party in this research. On average, green political parties occupied 13,5% of seats in Municipal Councils. In numerous municipalities green parties did not occupy any seats, whereas 51,11% of seats were occupied by green parties in the municipality of Utrecht, which is the highest scoring municipality.

3.2.3. Council M&A Political party composition

For this variable a dataset is used in which all Aldermen and their respective political parties are displayed for the period 2014-2018, with N=388 (Proszowska, Jansen and Denters, 2020). Municipalities which had one or more Aldermen who represent a green political party were assigned a score of 1, whereas municipalities with no Aldermen who represents a green political party were assigned a 0. The same parties as described in the previous variable were used here. If an Alderman was part of a combination of parties which included at least one green party, a score of 1 was assigned as well. Figure 3 shows that in 38% of all municipalities one or more Aldermen represents a green political party. This comes down to a total of 148 municipalities.

3.2.4. Local Energy Cooperatives

Every year, HIER Opgewekt publishes a detailed rapport about sustainability, climate and the environment in the Netherlands in the Local Energy Monitor (*or Lokale Energie Monitor*; Schwenke, 2020). Since 2015, an overview of all local energy cooperatives and their locations in the Netherlands is provided. These lists of 2015, 2016 and 2017 were checked and the respective locations were assigned to the municipalities they are located in (Schwenke, 2016; Schwenke 2017). The average amount of present cooperatives throughout these three years was calculated and used as the workable data for this variable. Figure 3 shows that throughout 2015 to 2017, on average 0,604 energy cooperatives were present, with N=388. In many municipalities no energy cooperatives were present throughout 2015 to 2017, with a maximum of five energy cooperatives in 2015 and six energy cooperatives in 2016 and 2017 in Súdwest-Fryslân, the highest scoring municipality.

3.2.5. Income Level

Data from Statistics Netherlands were taken to check for the income level of households per municipality, with N=388 (CBS, 2017). Three types of data are present in their datasets about household income: the percentage of households that falls in the category with the lowest 40% of average household income, the percentage of household that falls in the category with the highest 20% of average household income, and in between both of these percentages. Data from the second category of 2014, 2015 and 2016 was taken and, as can be seen in figure 3, the average of the three years is constructed. The data show that in the period of 2014-2016 on average 22,35% of households possess 20% of the average highest income. The minimum score is reached by the municipality of Kerkrade, which is 10,03%. The highest score, of 48,6%, is achieved by the municipality of Rozendaal.

3.2.6. Education Level

Data from Statistics Netherlands were taken to check for the education level in municipalities, with N=381 (CBS, 2020). The dataset distinguishes a low level of education, a medium level of education and a high level of education. This research focuses primarily on the high level of education. The database of Statistics Netherlands unfortunately does not provide an explanation about what exactly a high level of education in the database entails, but in a less recent education database it entails having a college degree from either a university of applied sciences or an academic university. The dataset rounds to numbers of thousands. The percentages are, thus, not entirely accurate. It is noteworthy that these data are about the education level of the entire labour force, rather than just households. As with income level, the average high education level of the years 2014-2016 was calculated. Figure 3 shows that on average 30,0% of the labour force has a high level of education in the period 2014-2016, with a minimum of 14,3%. The municipality of Bergen in the province of Limburg, reached this percentage. The municipality of Utrecht once again has the highest score, with a highly educated population of 60,65%.

Figure 3: Descriptive Statistics	**N**	**Minimum**	**Maximum**	**Mean**	**Std. deviation**
Average residential PV 2015-2017	388	54,33	15496,33	3353,73	2598,37
Average residential PV per capita 2015-2017	388	0,02	0,39	0,01	0,05
SDE Subsidized solar energy in kW 2008-2010	376	0,00	7,28	1,64	1,42
Aldermen in green political parties 2014-2018	388	0	1	0,38	0,49
Percentage seats green political parties Municipal Council 2014-2018	374	0,00	0,51	0,13	0,11
Average amount of energy cooperatives 2015-2017	388	0,00	5,67	0,60	0,86
Average percentage households 20% highest income	388	10,03	48,6	22,35	5,78

Figure 3: Descriptive Statistics for all dependent and independent variables

4. Analysis

This chapter revolves around the analysis of the data described in the previous chapter. A correlation matrix is provided which highlights the Pearson's correlation coefficients of the dependent variable vis-à-vis all independent variables individually and population size. In addition, an overview is provided of Pearson's coefficients of relationships between several independent variables that draw from the sub-hypotheses from the theoretical framework chapter. These relationships receive extra attention, because they are not made apparent in the multiple regression analyses which are described in this chapter as well. Multiple regression analyses are typically used to estimate the effect of numerous independent variables on the dependent variable (Explorable, 2009). The main benefit of a multiple regression analysis is that it is possible to insert multiple variables at once, so the variables control for the effects of one another. In this research multiple regression analyses are an optimal way to estimate the effects of all six independent variables on the different operationalizations of residential PV simultaneously.

The models are used to accept or reject the hypotheses of this research. An interpretation of the data is given that takes into account the significance, strength and direction of the described relationships. In all analyses in this chapter, the dependent variable is operationalized in two distinct ways: as average annual residential PV production from 2015 to 2017 or as average annual residential PV production from 2015 to 2017 per capita.

Figure 4 reveals the Pearson's correlation coefficients for the relationships between the dependent variables and the independent variables, as well as for relationships between the independent variables together. Within bivariate relationships, the Pearson's coefficient is used to measure whether it constitutes a negative or a positive direction in and the strength of a linear relationship (Ganti, 2020). The outcome is always between -1 and +1, where -1 shows a negative linear relationship, 0 shows no linear relationship and +1 illustrates a positive linear relationship (Minitab, 2019). Akoglu (2018) provides a table of three different interpretations of Pearson's correlation coefficients. Figure 5 summarizes the interpretation of the Political Science Department at Quinnipiac University of seven different strengths of Pearson's correlation coefficients. This interpretation is used to describe the relevant correlation coefficients of figure 4.

Pearson's correlation coefficient is not the optimal way for checking the strength and direction of a bivariate relationship where one variable is categorical, which is the case for Aldermen political party composition. Wherever this variable was used to check for the strength and direction of a relationship, an independent samples t-test was performed instead, which is a parametric method that determines whether the population means are significantly different from one another (Kent State University, 2020).

Figure 4: Correlation coefficients	1	2	3	4	5	6	7	8	9
1: Average residential PV 2015-2017 (N=388)	-	-	-	-	-	-	-	-	-
2: Average residential PV per capita 2015-2017 (N=388)	0,01	-	-	-	-	-	-	-	-
3: SDE Subsidized solar energy per capita 2008-2010 (N=376)	0,02[1]	0,53**[1]	-	-	-	-	-	-	-
4: Aldermen in green political parties 2014-2018 (N=388)	0,25**[1]	-0,21**[1]	-0,14**[1]	-	-	-	-	-	-
5: Percentage seats green political parties Municipal Council 2014-2018 (N=374)	0,27**[1]	-0,26**[1]	-0,20**[1]	0,65*	-	-	-	-	-
6: Average amount of energy cooperatives 2015-2017 (N=388)	0,4**[1]	0,12*[1]	0,18**	0,14**[1]	0,18**[1]	-	-	-	-
7: Average percentage households 20% highest income (N=388)	-0,35**[1]	-0,16**[1]	-0,13**	0,05	0,14**	-0,21**	-	-	-
8: Average percentage highly educated people (N=381)	0,17**[1]	-0,30**[1]	-0,21**	0,46**	0,63**	0,16**[1]	0,37**	-	-
9: Population (N=388)	0,67**	-0,29**	-0,19**	0,29**	0,35**	0,33**	-0,23**	0,34**	-

*Figure 4: Pearson's coefficients for all dependent and independent variables and population size, as well as Pearson's coefficients for relationships amongst independent variables. *p<0,05; **p<0,01 (two-tailed test). [1]= Pearson's coefficients for a relationship which includes a hypothesis from the theoretical framework.*

Figure 5: Coefficient interpretations	Correlation coefficient	Relationship strength
	-1 or 1	Perfect
	-0,9 or 0,9	Very strong
	-0,8 or 0,8	Very strong
	-0,7 or 0,7	Very strong
	-0,6 or 0,6	Strong
	-0,5 or 0,5	Strong
	-0,4 or 0,4	Strong
	-0,3 or 0,3	Moderate
	-0,2 or 0,2	Weak

-0,1 or 0,1	Negligible
0	None

Figure 5: Interpretations of Pearson's correlation coefficients of the Political Science Department at Quinnipiaic University

Subsidized solar energy per capita is strongly positively associated with residential PV per capita, with a Pearson's correlation coefficient of 0,53. This means the more subsidies per capita are procured in a municipality, generally more residential PV per capita is expected to be produced. The Pearson's correlation coefficient of 0,02 indicates there is practically no relationship between subsidized solar energy per capita and residential PV. This means no sensible prediction of produced residential PV can be made based on data of SDE subsidized solar energy per capita.

In 143 municipalities where at least one green party is represented in the local executive government the mean subsidized solar energy in kW is 1.39, compared to an average of 1.79 kW in 233 municipalities where no green party is represented in the local executive government, which is significant at p=0,042. With this, hypothesis 3a, if one or more green political parties are represented in the local executive government, more subsidies are procured within a municipality, is rejected.

Subsidized residential PV per capita is weakly negatively associated with the share of green parties in the Municipal Council, with a Pearson's correlation coefficient of -0,21. With this, hypothesis 2a, the more seats are occupied by green parties within the Municipal Council, the more subsidies are procured within a municipality, is rejected, because of the negative direction of the relationship.

In 148 municipalities where at least one green party is represented in the local executive government the mean residential PV production per capita is 0,09 kW, compared to an average of 0,11 kW in 240 municipalities where no green party is represented in the local executive government, which is significant at p=0.000. This entails that in municipalities where a green party is represented in the local executive government generally less residential PV per capita is expected to be produced in comparison to municipalities where no green party is represented in the local executive government. When performing the same test for produced residential PV in absolute numbers, the same conclusion cannot be drawn. The mean produced residential PV in the 148 municipalities where no green party is represented in the local executive government is 4166,08 kW, compared to 2852,77 kW where no green party is represented in the local executive government, which is significant at p=0,000. This means that in municipalities where a green party is represented in the local executive government generally more residential PV is expected to be produced.

The share of green parties in the Municipal Council is weakly to moderately negatively associated with residential PV per capita, with a Pearson's correlation coefficient of -0,26. This means the higher the share of green parties is in the Municipal Council in a municipality, generally less residential PV per capita is expected to be produced. The share of green parties in the Municipal Council is also weakly to moderately associated with strongly residential PV per capita, but now positively. The Pearson's correlation coefficient is 0,27. This means the higher the share of green parties is in the Municipal Council in a municipality, generally more residential PV is expected to be produced.

The strength of the relationship between the average amount of energy cooperatives in a municipality and residential PV per capita is positive but negligible, as the Pearson's correlation coefficient is 0,12. This suggests that the higher the average amount of energy cooperatives is in a municipality, the higher the residential PV per capita is expected to be, but to a limited extent. However, the strength of the relationship between the average amount of energy cooperatives in a municipality and residential PV is strongly positively associated, with Pearson's correlation coefficient is 0,4. This means the higher the average amount of energy cooperatives is in a municipality, more residential PV is expected to be produced.

In 148 municipalities where at least one green party is represented in the local executive government the average amount of energy cooperatives is 0,75, compared to an average of 0,51 in 240 municipalities where no green party is represented in the local executive government, which is significant at p=0.007. With this, hypothesis 4b, if one or more green political parties are represented in the local executive government, more local energy cooperatives are active in that municipality, is accepted. The share of green parties in the Municipal Council is weakly to negligibly positively associated with the average amount of energy cooperatives in a municipality, with a Pearson's correlation coefficient of 0,14, which is significant at α = 5%. With this, hypothesis 4a, the more seats are occupied by green parties within the Municipal Council, the more local energy cooperatives are active in that municipality, is accepted.

The share of households that possesses a disposable income equivalent or higher to the highest twenty percent of disposable income in the Netherlands is weakly negatively associated with the average amount of energy cooperatives in a municipality, with Pearson's correlation coefficient is -0,21, which is significant at α = 5%. With this, hypothesis 5a, the higher the average household income is in a municipality, the more local energy cooperatives are active in a municipality, is rejected. The percentage of municipal populations that is highly educated is weakly to negligibly positively associated with the amount of energy cooperatives in a municipality, with Pearson's correlation coefficient is 0,16, which is significant at α = 5%. With this, hypothesis 6a, the larger the share of highly educated people is in a municipality, the more local energy cooperatives are active in a municipality, is accepted.

The share of households in a municipality that possesses a disposable income equivalent or higher to the highest twenty percent of disposable income in the Netherlands is weakly to negligibly negatively associated with residential PV per capita, with a Pearson's correlation coefficient of -0,16. This indicates that in municipalities where the share of households with a high income is high, generally less residential PV per capita is expected to be produced, but to a limited extent. The share of households in a municipality that possesses a disposable income equivalent or higher to the highest twenty percent of disposable income in the Netherlands is moderately to strongly negatively associated with residential PV, with a Pearson's correlation coefficient of -0,35. This indicates that in municipalities where the share of households with a high income is high, generally less residential PV is expected to be produced.

The percentage of municipal populations that is highly educated is moderately negatively associated with residential PV per capita, with Pearson's correlation coefficient is -0,3. This suggests that in municipalities with a high share of highly educated people, less residential PV per capita is expected to be produced. However, the percentage of municipal populations that is highly educated is weakly to negligibly positively associated with residential PV, with Pearson's correlation coefficient is 0,17. This means that in municipalities with a high share of highly educated people more residential PV is expected to be produced, but to a limited extent.

4.1. Regression Analysis

Various multiple regression analyses were performed to check for the linearity and the significance of the independent variables in relationship to both operationalizations of residential PV. Within these models is distinguished between model 1, which zooms in solely on population characteristics of municipalities and model 2, which includes all independent variables. Separate tables for model 1 and model 2 are provided, which show an overview of b-coefficients and significance levels of the independent variables when they are being controlled for by the other independent variables within the model, as well as population size. The R-squareds are also displayed in the models, which is ‘a statistical measure that represents the proportion of the variance for a dependent variables or variables in a regression model’ (Hayes, 2020). In other words, the R-squared indicates the variance of residential PV that can be explained by independent variables which are included in the model. Procured subsidies and the average amount of energy cooperatives are excluded from the first model, as these are independent variables that are hypothesized to be influenced by numerous other independent variables. These variables are included in the second model, so the effect of those two variables on the overall effect of all independent variables on residential PV can be observed.

Model 1	***B***	***Sig.***	***B***	***Sig.***
1: Council of M&A party composition (N=388)	-0,007	0,249	239,78	0,359
2: Municipal Council party composition (N=374)	-0,05	0,123	1874,96	0,159
3: Household income (N=388)	-0,002**	0,001	-103,82**	0,000
4: Education level (N=381)	-0,021	0,644	-389,76	0,836
5: Population divided by 10.000 (N=388)	-0,02**	0,000	212,77**	0,000
R-Squared	0,173		0,491	

Model 1: B-coefficients and significance levels of independent variables that are population characteristics for both operationalizations of residential PV, controlled for by population size.

Model 2	*B*	*Sig.*	*B*	*Sig.*
1: Council of M&A party composition (N=388)	-0,009	0,101	308,70	0,233
2: Municipal Council party composition (N=374)	-0,023	0,412	1692,12	0,200
3: Household income (N=388)	-0,001	0,062	-87,52**	0,000
4 Education level (N=381)	-0,054	0,177	-701,07	0,713
5: SDE subsidies (N=376)	0,014**	0,000	172,76**	0,017
6: Energy cooperatives (N=388)	0,006**	0,033	418,97**	0,001
7: Population	-0,001**	0,000	205,10**	0,000
R-Squared	0,384		0,519	

Model 2: B-coefficients and significance levels of all independent variables for both operationalizations of residential PV, controlled for by population size.

Within the first model, B-coefficients for all independent variables are either negative, or positive but insignificant. This suggests that just these population characteristics overall are not important explanatory factors when explaining residential PV. The included independent variables, controlled for by population size, explain 17,3% of the variance in produced residential PV per capita in Dutch municipalities and 49,1% of the variance in produced residential PV. When procured subsidies and the average amount of cooperatives are included in model 2, the independent variables explain 38,4% of the variance in produced residential PV per capita, an increase of variance explanation of 121,97%. The extent to which an increase is realized in the explanation of the variance of residential PV in absolute numbers by all independent variables is marginal, as the variance increased with just 2,8% to 51,9%.

Two formulas arise based on the multiple regression analyses performed in model 2. The formula for the first operationalization of residential PV is Y=0,119-0,009A-0,023B-0,001C-0,054D+0,014E+0,006F-0,001G, where variable A is Aldermen party composition, B is Municipal Council party composition, C is the income variable, D is the education variable, variable E is the subsidy variable, variable F is the energy cooperatives variable and variable G is population size. The numbers assigned to the variables entail that when all other variables are held constant, an increase of 1 in that particular variable is expected to lead to an increase of residential PV per capita by the number in front of the variable in the formula. For example, an increase of the percentage of highly educated people by 1 percent is expected to lead to a decrease of 0,054 residential PV per capita in a municipality.

The formula for the second operationalization of residential PV is Y=3730,522+308,7A+1692,12B-87,52C-701,07D+172,76E+418,97F+205,1G, where all variables are the same as described in the previous formula explanation. Similarly, an increase of 1 in a particular variable is expected to generate an increase of residential PV by the number in front of the variable in the formula. Based on the second model an appropriate estimation of whether to accept or reject a hypothesis can be made for all included variables. Beneath an enumeration of accepted and rejected hypotheses based on the two models is provided.

The B-coefficients of procured SDE subsidies are positive at 0,014 and 172,76 for both operationalizations of residential PV and are significant at α = 5%. This means hypothesis 1, the more subsidies towards residential solar PV panels are procured within a municipality, the more solar energy is generated in a municipality, is accepted. The B-coefficients of the average amount of energy cooperatives are both positive at 0,006 and 418,97 for both operationalizations of residential PV and are significant at α = 5%. This means hypothesis 4c, the more local energy cooperatives are active in a municipality, the more residential solar energy is generated in a municipality, is accepted.

The B-coefficients of Municipal Council composition are -0,023 and 1692,12 for both operationalizations of residential PV and are insignificant at α = 5%. This means hypothesis 2b, The more seats are occupied by green parties within the Municipal Council, the more subsidies are procured within a municipality, is rejected. The B-coefficients of Council of M&A composition are -0,009 and 308,70 for both operationalizations of residential PV and are insignificant at α = 5%. This means hypothesis 3b, if a green political party is represented in the local executive government, the more residential solar energy is generated in a municipality, is rejected.

The B-coefficients of household income are both negative at -0,001 and -87,52 for both operationalizations of residential PV. The second operationalization brings forth a statistically significant outcome, but the hypothesis includes a positive relationship rather than a negative relationship. This means hypothesis 5b, the higher the average household income is in a municipality, the more residential solar energy is generated in a municipality, is rejected. The B-coefficients of the average amount of the percentage of highly educated people are both negative at -0,054 and -701,07 for both operationalizations of residential PV and are insignificant at α = 5%. This means hypothesis 6b, the higher the average share of highly educated people in a municipality, the more residential solar energy is generated in a municipality, is rejected.

Based on the findings and interpretations in this chapter, figure 6 is constructed, which displays the accepted hypotheses as a green line and rejected hypotheses as an orange line. Five hypotheses are accepted and seven are rejected. The green lines resemble a positive significant relationship between variables, whereas the orange line resembles insignificant relationship or a significant negative relationship.

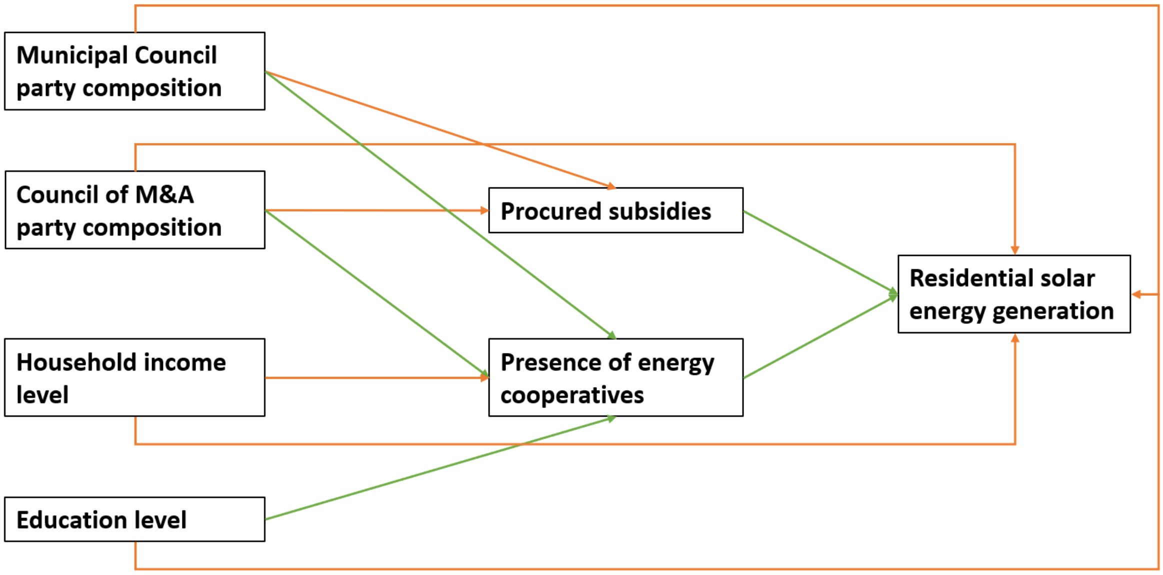

Figure 6: Accepted and rejected hypotheses

5. Conclusion

The main goal of this research was to investigate the extent to which procured subsidies for residential solar PV adoption, Municipal Council political party composition, Council M&A political party composition, the presence of local energy cooperatives, household income level and education level of individuals in municipalities explain residential PV adoption in Dutch municipalities. The corresponding research question is ''*What are factors that explain differences in residential solar energy generation between Dutch municipalities?*''. Various secondary databases were consulted to obtain relevant data for these variables for as many municipalities as possible. These data were quantitatively analysed and controlled for by population size, to arrive at correlation coefficients that explained the bivariate relationships individually, and after that various multiple regression analyses were performed to control for the effect of all variables simultaneously and to predict the effect of all variables on residential PV. Based on these analyses, five out of twelve hypotheses as compiled in the theoretical framework chapter were accepted and seven were rejected (Figure 6).

The two main factors that explain differences in residential solar energy generation between Dutch municipalities in this research are procured SDE subsidies and the average amount of energy cooperatives present in a municipality. The average amount of energy cooperatives is positively influenced by the share of green parties in a Municipal Council, having at least one green party that is represented in local executive government and the share of highly educated people in a municipality. These are all variables that help to indirectly explain differences in residential PV deployment across Dutch municipalities.

The findings of this research on subsidies and energy cooperatives coincide with empirical results on financial incentives and intermediary organizations identified in the literature, with the exception of the conclusion of Balcombe, Rigby and Azapagic (2013) who found that consumer uptake remained low in the UK despite significant governmental financial efforts. The explanatory factors that are identified in this research were generally found to have a similar effect in the literature. The results of this research remain scientifically relevant, though, seeing as the Dutch context is under researched and diffusion of residential PV across the country has not been sufficiently explained.

Factors that are not related to residential PV diffusion are Municipal Council political party composition, Council M&A political party composition, household income level and education level of individuals in municipalities. Both results of political party composition variables are more or less in line with the literature, as Palm (2016) and Dharshing (2017) found no significant effect of political orientation on residential PV uptake. Only Kwan (2012) found evidence that in the U.S. political party affiliation plays a role in the diffusion of residential PV, but the two-party system there differs from the Dutch local party system, where parties are more diverse and can more easily distinguish themselves from other parties. Based on what was found in the literature, the results on political variables of this research are not incredibly surprising. Local green parties are found to often have a high share of seats in the bigger municipalities in the Netherlands, which are the municipalities that turn out to generally score quite badly in terms of residential PV per capita. This research can function as an eye-opener to green local parties that they do receive relatively many votes in big municipalities, but they have generally not yet been able to drastically increase residential PV per capita, which should be one of their ecologist goals in municipalities.

The findings of this research on income coincide with those identified in the literature. Remarkably, the findings of this research on education only coincides with the article of Yi and Li (2014) and is contradicted by findings of three different scholars, who all individually refer to various scholars who found education level to be positively associated with PV uptake. It might be the case in the Netherlands that green parties have a high share of votes in the bigger municipalities where young people live and less space per capita is available for residential PV, which both negatively influence residential PV adoption rates. Because of the results of this research, education level can now be seen as less of an obvious predictor of regional PV uptake, as it adds strength to the findings of Yi and Li (2014) and this research debunks the theories of the other scholars. However, further research is required to confirm the findings about education of this research.

The findings of this research bring about various types of recommendations for local policymakers in the Netherlands. Subsidies for residential PV are no longer universally available in the Netherlands, but municipal governments can still choose to grant subsidies for residential PV. Seeing as solar panels currently are profitable enough without subsidies (Milieu Centraal, 2020), it might not be necessary to grant subsidies, but provide alternative financial incentives. It would, however, be advised to strongly take into account that these financial incentives address the barrier of high initial costs. Another opportunity is to make more people aware of the fact solar panels are in fact quite profitable on the long term and generally worth the investment, as it decreases electricity costs and it can increase the value of the home. It might be cheaper for municipal governments to advertise this fact instead of providing subsidies of thousands of euros, but that is up to the governments themselves to decide. Next to financial incentives, local policymakers should take action to increase the amount of energy cooperatives in their respective municipalities. Municipal governments can play a facilitative role here. Not only would the overall share of energy produced by renewable sources in a municipality increase because of the emergence of one or more energy cooperatives, it could also increase the overall exposure of solar energy, which could in turn lead to a higher residential PV adoption rate.

One of the strengths of this research is that in all consulted databases almost no data of municipalities were missing. For each variable, data on at least 374 municipalities out of 388 relevant municipalities were used. This makes the analysis and results quite valid. In addition, with the exception of the subsidy variable, the variables are logically chronologically ordered to improve the plausibility of causality. The study has numerous limitations as well. The study set certain parameters to be able to arrive at conclusions. However, these conclusions are not undisputed facts, but results that are concluded based upon models with a fairly high level of certainty, depending on those parameters. Furthermore, it has been established that the variables are correlated, but this does not immediately point to causality. With these findings clear expectations about the direction and strength of the relationships are formed. Further research can explore these relationships more, which can add strength or debunk the findings of this research and possibly help policymakers to make informed decisions about increasing residential PV adoption rates.

Data on SDE subsidies were used from the years 2008 to 2010, because no more recent overview could be consulted via secondary sources. After SDE subsidies were procured, municipal governments themselves did continue to procure subsidies. Ideally an overview of those subsidies would be used if this study were to be replicated for the years 2014 to 2016, to make it better comparable to the other independent variables and to improve the plausibility of causality. The same logic can be applied to the energy cooperatives variable, for which data were used from the years 2015 to 2017. No prior data were available, but more ideally data from 2014 to 2016 were used. In future research it could be intriguing to look into different financial incentives from subsidies as well, as these might be better able to explain the more recent changes in residential PV generation.

This bachelor thesis had to be conducted in a timespan of around ten weeks, which is a relatively short amount of time for a research. If less time constraints were present, possibly more variables or different operationalizations of researched variables could have been included in this research. A variable that can help to explain residential PV in the Netherlands could be the average age in a municipality. Young people are generally poorer and despite voting for green parties to a relatively large extent, do often not have the means to install solar panels for their homes. This is a potential controlling variable for income and both political variables, which could partially explain their insignificance in the regression models. Municipalities could also be coded differently in further research, into for instance very small, small, big and very big in terms of population size, to see if the differences are large and if this helps to explain residential PV adoption.

In future research, it could also be interesting to look not at the share of green parties, but left-right political orientation, as green parties are usually parties that emphasize left-wing values such as equality (Carter, 2013; Ennser, 2010). A potential explanation for income level to be negatively associated with residential PV in the Netherlands is that poorer people tend to vote for parties that emphasize left-wing values such as equality, which generally include green parties. It is worth researching whether residential PV would be positively associated with a higher share of households with a low income, as this could help to explain why a higher share of a households with a high income is negatively associated with residential PV based on this research.

In future research attention should be paid to different operationalizations of residential PV. An option is to focus on a longer time span. Within this timeframe different periods of years can be compared to one another to see if there are differences. It could also be intriguing to not look at the average residential PV over the course of a few years, but to look at factors which influence growth in percentages in terms of produced residential PV. Results that explain the growth in the Netherlands are equally relevant to the results of this research and can further help local policymakers to determine what kind of policies could help them achieve growth in residential PV. Lastly, it is worth investigating if a different operationalization of the Aldermen variable yields different results than this research. Instead of assigning a 0 to a municipality where no green party is represented in the local executive government and a 1 to a municipality where one or more green parties are represented, a researcher could look at the percentage of green parties that are represented in the local executive government and see if these results differ from the results of this research.

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