RESIDENTIAL GRID-CONNECTED PHOTOVOLTAICS ADOPTION IN NORTH CENTRAL TEXAS:

LESSONS FROM THE SOLARIZE PLANO PROJECT

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Residential Grid-Connected Photovoltaic (GPV) systems hold remarkable promise in their potential to reduce energy use, air pollution, greenhouse gas emissions, and energy costs to consumers, while also providing grid efficiency and demand-side management benefits to utilities. Broader adoption of customer-sited GPV also has the potential to transform the traditional model of electricity generation and delivery. Interest and activity has grown in recent years to promote GPV in north central Texas.

This study employs a mixed methods design to better understand the status of residential GPV adoption in the DFW area, and those factors influencing a homeowner's decision of whether or not to install a system. Basic metrics are summarized, including installation numbers, distribution and socio-demographic information for the case study city of Plano, the DFW region, Texas, and the United States. Qualitative interview methods are used to gain an in-depth understanding of the factors influencing adoption for the Solarize Plano case study participants; to evaluate the effectiveness of the Solarize Plano program; and to identify concepts that may be regionally relevant. Recommendation are presented for additional research that may advance GPV adoption in north central Texas.

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CHAPTER 1

INTRODUCTION TO THE RESEARCH PROBLEM

1.1 Summary

Grid-connected photovoltaic (GPV) systems have emerged as “the fastest growing power generation technology in the world (REN21, 2009, p. 12).” As a scalable, emissions free, distributed electric generation technology that is becoming financially accessible to broader market segments, GPV has the potential to play an important role in strategies to reduce air pollution and greenhouse gas emissions, increase reliability of the electric grid and energy independence at a variety of scales, and decrease reliance on fossil fuels. Broader adoption of customer-sited GPV also has the potential to transform the traditional model of electricity generation and delivery. For all of these reasons, GPV has received increasing attention and interest among a variety of stakeholders including utility customers, utilities, industry, non-profits and government agencies at all levels, with many seeking to overcome barriers to broader GPV adoption. Unfortunately, efforts to promote GPV often proceed without a full understanding of factors, especially context specific, which could contribute to increasing adoption goals. Research is often missing on the status and impact of regional policies and programs; stakeholder perspectives and experiences, particularly customer/adopter perspectives; and baseline measures for tracking adoption such as adoption rates and installed cost as distributed geographically and across time.

This study provides information pertinent to GPV market development in North Central Texas and utilizes the Solarize Plano project as a case study with regional relevance. First, the status of GPV adoption in Plano and the DFW region are described through basic metrics over time and compared to those for Texas and the United States. Regional PV system distribution and basic socio-demographic variables are summarized, and areas of interest are highlighted. After presenting the regional landscape, the study evaluates effectiveness of the 2013-2014 Solarize Plano project in overcoming barriers and facilitating adoption of residential grid-connected photovoltaic (GPV) systems in Plano, Texas and identifies lessons from the Solarize Plano project that may advance GPV adoption in the Dallas- Fort Worth (DFW) region. In depth interviews conducted with Solarize Plano participants, project organizers, and project solar installers are analyzed to identify important concepts in GPV adoption and evaluate the effectiveness of the Solarize Plano model for overcoming barriers to solar adoption. These concepts are compared with those found in the literature on solar adoption, and key themes of system performance and "payback" are explored in depth. Finally, key lessons from the Solarize Plano model are discussed in the context of efforts to advance GPV in the DFW region.

1.2 Grid-Connected Photovoltaic Systems

In 1839, French physicist Edmund Becquerel discovered a remarkable phenomenon, the ability of certain materials to produce an electron flow when exposed to sunlight (Ecyclobeamia, 2003; Honsberg and Bowden, 2016). This property, later called the "photovoltaic effect" has been harnessed, developed, and engineered over the years into what is becoming one of the world's leading power generation technologies.

Unlike conventional electric power generators, photovoltaic (PV) systems use semi-conductor materials to generate electricity when exposed to the sun. Other components collect, direct, and transform the electron flow into usable DC or AC electricity. Until the late

1990’s, PV technologies were used primarily in “off grid” settings where extension of power lines would prove technically or financially impractical. In such applications, the electricity produced can directly power loads or be stored in batteries for later use. In fact, PV systems in remote settings are largely battery-powered systems, charged by the sun.

The development of the grid-synchronized inverter in the early 1990’s, proved to be a “game changer” for the PV market. This innovation enables PV systems to smoothly interconnect with the utility grid, allowing for an ebb and flow of electricity consumption and production that varies with customer demand and available sunlight. Grid-connected PV (GPV) systems do not require battery backup and can be sized to meet a portion or all of the end user’s electricity demand. Importantly, GPV systems open up the possibility for individuals distributed anywhere on the electric grid to provide their own power when the sun is shining, draw power from the grid when the sun is not, and send excess electricity produced back to the grid for others to consume.

This technical innovation has brought about a significant increase in global demand for PV among several market segments (residential, commercial, utility), and has initiated or required legal and procedural innovations (Rogers, 2003) where deployed. Geographic areas with the largest GPV markets tend to be those where legal and procedural adjustments have been more smoothly enacted. Around the world, proponents of GPV have worked to reduce barriers and develop best practices for advancing the GPV market, at a variety of levels.

1.3 Grid-Connected Photovoltaic Systems in the Dallas-Fort Worth Region

Grid-connected photovoltaics stand to play an increasing role in the Dallas-Fort Worth (DFW) energy infrastructure. Several stakeholders are engaged in identifying and removing barriers to the regional GPV market. Approximately a quarter of the State's population, or an estimated 6.8 million people in 2014 (NCTCOG, 2014a) and their associated energy use are concentrated in DFW. The DFW population is expected to reach approximately 11.3 million by 2040 (NCTCOG, 2012) contributing to the already constrained air quality and electric grid.

Air quality from fossil fuel combustion including electric power generation persists as a regulatory, environmental, and health concern. Ten counties in the DFW region[1] have consistently failed to meet the USEPA's 8- hour ground level ozone standards (TCEQ, 2012). Meanwhile, ERCOT, the state's independent electricity system operator, has been actively restructuring grid planning and management in response to constraints in the DFW area and other regions with rapid population growth (Elliott, et al, 2007; ERCOT,2009; NBCDFW, 2015; Sakelaris, 2014, 2015). The recently passed federal Clean Power Plan (USEPA, 2015), limiting emissions from coal fired electric plants, is expected to impact regional grid planning as well (Sakelaris, 2015).

Like other areas of Texas, the regional GPV market has been stimulated by state policy requiring utility investment in renewable energy[2], including incentives for customer sited renewable energy (RE) systems (EUMMOT, 2013); and by falling global prices for PV system hardware. Local stakeholders, including government and non-government organizations such as the North Texas Renewable Energy Group (NTREG), utilities, and solar industry representatives,

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[1] TCEQ region 4

[2] Electric Substantive Rules 25.173. Chapter 25 (Public Utility Commission of Texas, 2013)

have become increasingly coordinated in their response to the emerging market and the associated constraints to market expansion.

Since spring of 2013, the North Central Texas Council of Governments (NCTCOG) has been working with member jurisdictions and local stakeholders to reduce regional barriers to adoption of GPV. NCTCOG is a voluntary planning association serving a 16 county region in North Central Texas, including 169 municipalities, 22 school districts, and 31 special districts. NCTCOG acts as the Metropolitan Planning Organization for member counties and addresses ozone nonattainment issues in 10 of these counties (NCTCOG staff, personal communication, September 12, 2014). In late 2013, NCTCOG was awarded funding from the U.S. Department of Energy (USDOE) to participate in the Solar Ready II (SRII) program. The SRII program is part of the USDOE's SunShot Initiative Rooftop Solar Challenge, "which strives to make solar energy cost-competitive with other forms of energy" (NCTCOG, n.d.b).

With limited funding, the NCTCOG SRII initiative has focused primarily on regional implementation of Best Management Practices (BMPs) in the areas of solar permitting. For two years, the NCTCOG has shared educational resources, BMPs, and successful models for reducing GPV barriers and costs with members and stakeholders. They have hosted regular meetings and workshops, and have obtained feedback from stakeholders via surveys and meeting or workshop breakout sessions. As of October 2015, NCTCOG SRII has sponsored 10 meetings or trainings (Table 1). Twenty-six of 169 NCTCOG member municipalities (Table 2) as well as the DFW Airport have participated.

Table 1. *North Texas Solar Energy Events Promoted or Sponsored by NCTCOG*

Date	Event	Sponsor
October 3, 2015	DFW Solar Tour	NREG
June 12, 2015	Solar Ready II Meeting	NCTCOG-SRII
March 30-31 2015	Solar Energy System Training	NCTCOG-SRII
October 21, 2014	Solar Permitting and Solar Ordinance Training	NCTCOG-SRII
October 4, 2014	DFW Solar Tour	NREG
September 30, 2014	Solar Ready II North Texas Solar Electric Permit Checklist Workshop	NCTCOG-SRII
August 27 2014	PACE and LEED 4: New Opportunities for Financing Energy and Water Efficient Green Buildings and Retrofits	NCTCOG-SRII
June 17, 2014	Solar Ready II Meeting	NCTCOG-SRII
May 15, 2014	Firefighter and 1st Responder Solar Energy System Safety Workshop	NCTCOG-SRII
March 6, 2014	Solar Ready II Kick-Off Meeting	NCTCOG-SRII
January 11, 2014	North Texas Renewable Energy Group "Solarize Your Neighborhood" Networking Event	NTREG
December 11, 2013	Solar Ready II Workshop	NCTCOG-SRII
December 4, 2013	The Next Big Energy Play in Texas – Huge Solar	TREIA
October 5 2013	DFW Solar Tour	NTREG
May 20, 2013	Solar Powering Your Community Workshop	NCTCOG

Source: NCTCOG (n.d.b) and NCTCOG staff (personal communication, September 8, 2014)

At the time of writing, the NCTCOG continues to facilitate this regional effort and has achieved the following outcomes: the creation of a “NCTCOG Local Government Solar Ready II Toolkit,” a model streamlined permit checklist proposed for adoption by member agencies, and development of a central website, http://gosolarnorthtexas.org/, aimed at providing information to the following audiences: 1) those interested in installing PV, 2) local governments, and 3) the solar industry (NCTCOG, n.d.a).

Table 2. *SRII Participants*

	Population	Submitted Questionnaire	Submitted permitting BMP priorities	SRII Letter of Commitment	SRII Resolution Adopted	SRII Meetings** Attended
Aledo*	3110					1
Allen	92,020	Y	Y			1
Arlington	379,577	Y	Y			3
Benbrook	22,206	Y	Y			4
Burleson	39,051	Y				1
Carrollton	126,700	Y				1
Cedar Hill	46,663	Y	Y		Y	1
Dallas	1,257,676	Y	Y			4
Denton	123,099	Y	Y			2
DFWIA	NA	Y				0
Flower Mound	68,609	Y	Y			1
Fort Worth	792,727	Y				2
Frisco	2914		Y			2
Garland	233,638	Y				0
Granbury	8,779	Y	Y			2
Grand Prairie	185,453					1
Irving	228,653	Y	Y			4
Kennedale	7394					1
Lewisville	101,074	Y	Y			1
Little Elm	32,701	Y	Y			1
Mansfield*	62,246					1
McKinney*	156,767					1
Mesquite	144,416					1
North Richland Hills	67,317	Y		Y		1
Plano	274,409	Y	Y	Y	Y	3
Richardson*	108,617					2
River Oaks	7,619	Y				0
Rockwall	41,785					1
Southlake	28,234	Y	Y			4
University Park	31,591		Y			1
Waxahachie	32,344	Y				1

Notes: * Attended Meetings but not listed by NCTCOG as SRII partners
** Does not include 1st (pre- SRII) NCTCOG Solar meeting or SRII trainings
Source: Participation summary (NCTCOG 2014b) and Population data from U.S. Census (2014a).

Other important outcomes include networking and dialog among regional stakeholders about non-permit related barriers to GPV in addition to permit related barriers, and potential strategies for addressing them. The Solarize Plano project, which will be evaluated and used as a lens through which to view barriers and drivers to regional GPV, developed after project organizers attended a presentation on the Solarize model at the first NCTCOG solar meeting.

A variety of stakeholders are negotiating direction for the DFW GPV market. While NCTCOG has obtained feedback from participants on barriers especially related to the SRII focus area of permitting, it is clear that the lack of even basic baseline data on the status of GPV as well as more comprehensive data on the barriers and potential drivers for GPV adoption, especially from a customer perspective, remain a significant limitation to understanding and advancing GPV adoption in the DFW region. Using a mixed-methods design, this study aims to contribute to regional strategies for increasing GPV deployment/adoption by achieving the following research objectives:

1) Summarize baseline metrics and distribution for GPV adoption in the case study area and the region and compare to similar metrics for Texas and the U.S.
2) Identify concepts important to GPV adoption from an end user perspective in the DFW area.
3) Evaluate effectiveness of the Solarize Plano project in overcoming customer barriers to GPV adoption.
4) Identify lessons from the Solarize Plano project and installer perspectives to formulate recommendations for increasing GPV in the DFW area.

After synthesizing existing research relevant to GPV adoption (Chapter 2), the status of GPV adoption in Plano and the DFW region are described through basic metrics over time and compared to those for Texas and the United States. Regional PV system distribution and basic socio-demographic variables are summarized, and areas of interest are highlighted (Chapter 3). The Solarize Plano model is evaluated for effectiveness in overcoming barriers to GPV adoption from an end user perspective (Chapter 4). In depth interviews conducted with Solarize Plano participants, project organizers, and project solar installers are analyzed to identify important concepts in GPV adoption and evaluate the effectiveness of the Solarize Plano model for overcoming barriers to solar adoption. These concepts are compared with those found in the literature on solar adoption, and key themes of system performance and "payback" are explored in depth. Socio demographic characteristics and adoption measures including installed price will be compared between program participants and these measures for Plano, DFW, Texas and the U.S. Finally, key lessons from the Solarize Plano model are discussed in the context of efforts to advance GPV in the DFW region (Chapter 5).

CHAPTER 2

REVIEW OF THE LITERATURE

Grid-connected photovoltaics (GPV) have the potential to play a role in reducing regional air pollution and greenhouse gas emissions, increasing reliability of a constrained electric grid, promoting local energy resources and the associated economic development, and generally decreasing reliance on fossil fuels. A variety of stakeholders, including the NCTCOG's Solar Ready II initiative, seek to advance GPV in the region. This research aims to support such efforts by clarifying the status of GPV adoption in the region and identifying locally relevant concepts and strategies related to GPV adoption, with an emphasis on factors important to potential system adopters/consumers.

Residential GPV systems represent a relatively new technology that someone must decide to purchase or lease to generate some or all of their electricity. The literature has been reviewed for concepts, theories, and methodological approaches relevant to understanding factors, including policies and programs that encourage or discourage people from purchasing or leasing GPV. Relevant literature draws from the fields of technological innovation, market economics, consumer/individual decision-making, and behavior change. Key theoretical approaches and concepts repeated across studies are presented below, with special attention given to concepts appearing in adopter/customer-focused research. Concepts common to both "top-down" research, such as policy or macroeconomic analyses, and adopter-focused and expert research will also be highlighted.

2.1 "Top-down" Perspective on Benefits, Barriers, and Strategies for GPV Market Acceleration

Since GPV entered the marketplace, a body of literature has developed to describe the key benefits and barriers to GPV "market development," with regular contributions from industry (GTM/SEIA, 2014; Solar Electric Power, 2001), non-profit solar research organizations (Sherwood 2009, 2010, 2011, 2012, 2013, 2014; Solar Foundation, GW Solar Institute & BW Research Partnership, 2015), and government agencies, including technical and policy reports produced by the national and international energy think tanks (Garve, Latour, and Sonvilla, 2012; Lopez-Polo, Haas, & Suna, 2007, REN21, 2009;) and U.S. federal energy laboratories (Barbose, 2014; Barbose & Darghouth, 2015a, b; Barbose, Wiser, & Bolinger 2006; NREL, 2015). I refer to this body of literature as representing the "top-down" perspective, as generally speaking this body of research is high-level policy analysis that does not include research into the perspectives of potential or actual adopter/consumers.

Benefits of GPV discussed in this body of literature include: environmental (Spiegel, Greenberg, Kern & House, 2000; USDOE, 2010; USEPA, 2016), energy independence (Berman and O'Connor, 1996; USDOE, 2010; USEPA, 2016), demand-side and grid-management (Aljlan, 1999; Hill, 1994; Hoff and Shugar, 1995; Starrs and Wegner, 2001), and economic development (Herig, 2006; Sterzinger and Svrcek, 2005; USDOE, 2010; USEPA, 2016). Solar electric systems require no fuel, produce no emissions from electricity production (Union of Concerned Scientists (UCS), n.d.), have "minimal" product life-cycle emissions (USC, n.d.), and most areas in the U.S. have suitable solar radiation for PV to be an option for power production (NREL, 2015).

As a distributed generation technology located closer to the point of consumption than traditional centralized generation, GPV can reduce system losses due to electricity transmission and distribution (Hoff and Shugar, 1995). Additionally, the solar industry and other renewable energy industries tend to be more labor intensive than their fossil fuel industry counterparts, and are attributed with comparatively more job creation potential (UCS, n.d.). According to the Solar Foundation's National Solar Jobs Census (Solar Foundation et al., 2015) "one out of every 78 new jobs created in the U.S.…or 1.3% of *all* new jobs [emphasis added] from 2013 to 2014 was created by the solar industry (Solar Foundation et al., 2015)."

Both technical and non-technical barriers to GPV are discussed in the literature. Globally and in the U.S., public and private sector investment has been directed to improving performance and durability of GPV system components. Public sector investment has steadily increased since 2006, with the bulk of PV research and development (R&D) funding coming from the private sector (Feldman, 2012). As GPV technology has improved and adoption has increased over the past decade, the discussion of technical barriers to GPV has shifted from focusing on the need for increased panel efficiency (sunlight to electricity conversion), decreased costs of materials and production, and increased component durability (Solar Electric Power, 2001), to issues with grid integration and saturation (Garve, Latour, and Sonvilla , 2012; Lindt, Fox, Ellis, & Broderick, 2013; Paidipati, Frantzis, Sawyer & Kurrasch, 2008; Stanfield and Vanega, 2015; Wesoff, 2014). In fact, the issue of grid integration is being increasingly used by utilities to justify reduced customer incentives for GPV (Kind, 2013; Sommer and Samuke, 2016; Warrick, 2015), and will likely continue to be an important part of the discourse.

Non-technical barriers to GPV frequently cited in "top-down" analyses include: legal and institutional barriers such as policies, permitting, codes, and institutional and/or utility procedures, that make installation and grid interconnection difficult and/or payback time more costly (Barnes and Vernado, 2010; Brooks, 2012; Garve, Latour, M., & Sonvilla, P. M., 2012; Haynes and Whitaker, 2007; IREC, 2013; NNEC, Vote Solar, IREC, & Solar Alliance, 2008; Pitt, 2008; Sherwood, 2013; Solar Electric Power, 2001); financial barriers such as high initial cost (Ardani et al., 2013; Friedman et al 2013; Solar Electric Power, 2001) and lack of financing (Ardani et al 2013; Pitt 2008; Solar Electric Power, 2001); and educational or informational barriers (Solar Electric Power, 2001). Several technical and non-technical barriers discussed contribute to the installed cost of GPV, including both hardware and "soft costs" such as marketing and customer acquisition, system design, installation labor, permitting and inspection costs, and installer margins" (Barbose, 2015a, p. 16). Soft costs represent a significant portion of total installed costs, an estimated 64% of residential installed costs in 2012 (Friedman et.al, 2013).

Policy strategies implemented or proposed to address the legal, institutional, and cost barriers described above, and discussed extensively in the literature include: favorable net metering[3] policies (Barnes & Vernado, 2010; IREC & Vote Solar, 2013, 2014), interconnection standards[4] (IREC & Vote Solar, 2013, 2014), renewable portfolio standards[5] (RPS) (Barbose ,

[3] Net metering "allows customers to send excess energy from an onsite renewable energy system back to the grid," and receive a credit for that energy (IREC 2016." Bidirectional meters allow a 1:1 credit; however, advanced meters allow the utility to charge different rates for incoming and outgoing electricity.

[4] Interconnection Standards, or standard interconnection rules, "establish processes and technical requirements that apply to utilities within the state and reduce uncertainty and delays that clean distributed generation systems can encounter when obtaining electric grid connection (NGA, 2010).

2014; Barbose & Darghouth, 2015b) especially with “solar carve outs (SEIA, 2015),” financial incentives, solar rights laws (GoSolar California, 2016), and streamlined and consistent permitting and reduced permitting fees (Ardani et al, 2013; Brooks, 2012; IREC & Vote Solar, 2013, 2014; Pitt, 2008). The Energy Policy Act of 2005 (EPA, 2005), the Emergency Economic Stabilization Act of 2008 (EESA, 2008), and the 2009 American Recovery and Reinvestment Act (ARRA, 2009) all created or extended important tax incentives, and other funding support for renewable energy technologies, including GPV. The 30% Federal Investment Tax Credit (ITC), for which residential GPV installations have qualified along with larger systems since 2008 was set to expire in 2016; however, the 30% ITC was recently extended to 2021 for residential projects and to 2024 for commercial and utility projects (Pentland, 2015).

Recently, some state and local governments have authorized Property Assessed Clean Energy financing (PACE) districts to allow loans for energy efficiency or renewable energy systems to be attached to a property and repaid through annual property taxes. PACE financing was thought to be a potentially important mechanism for supporting residential GPV; however residential PACE programs were successfully limited by mortgage companies during the mortgage crisis of 2007-2009 (Aston, 2011; California v. Federal Housing Finance Agency, 2011), and are at this time primarily available only to commercial projects.

Several sources track the status of policy best practices by state, including: the Interstate Renewable Energy Council (IREC), the North Carolina Solar Center (NCSC), the Vote Solar Initiative, and the Network for New Energy Choices (NNEC). IREC has published many documents on model policies, and since 2006 has collaborated with NCSC, the Vote Solar

[5] Renewable Portfolio Standards are state standards requiring electric utilities to purchase or generate a specified amount of their electricity from renewable sources.

Initiative, the NNEC, the Solar Alliance, and the Solar Foundation to produce "Freeing The Grid," an annual report card (now online) evaluating each state's net metering and interconnection policies (IREC, NNEC, Vote Solar, & Solar Alliance, 2007; NNEC, Vote Solar, IREC, & Solar Alliance, 2008, 2010; NNEC & Vote Solar, 2009; IREC & Vote Solar, 2013, 2014; IREC, Vote Solar, NCSC,NNEC, Solar Alliance, & Solar Foundation, 2011; IREC, Vote Solar, NCSC, and NNEC, 2012). IREC and the NCSC also maintain the Database of State Incentives for Renewables and Energy Efficiency (DSIRE) website, which summarizes the current status of solar favorable policies by state, and other incentives such as rebates or buyback rates, that vary by utility.

Non-technical barriers and policy "best practices" for addressing them vary significantly from state to state. Those states with the most extensive implementation of policy and programmatic best practices also have the most GPV installations by capacity and numbers (Barbose, 2014; IREC & NCSC, 2014). Unfortunately, little if any evaluative research for the effectiveness of the specific various policies exists, especially from and end user perspective. However, several trends and benchmarks are important to note.

Installed costs of GPV have fallen significantly over time for all sectors, with an 80% drop from 2008-2014 globally (IRENA), and a 50% drop from 2010-2014 in the U.S. (Barbose, 2015, p.17). This reduction is largely attributed to a sharp decline in PV module prices, which dropped an estimated 75% globally from 2009- 2014 (IRENA, 2014, p.75). Figure 1 shows trends in residential GPV installation capacity and costs (in the U.S.) along with a count of states implementing RPS policies (Barbose, 2014), and receiving grades of "A" or "B" (IREC, NNEC, Vote Solar, & Solar Alliance, 2007; NNEC, Vote Solar, IREC, & Solar Alliance, 2008, 2010; NNEC & Vote Solar, 2009; IREC & Vote Solar, 2013, 2014; IREC, Vote Solar, NCSC,NNEC, Solar Alliance, &

Solar Foundation, 2011; IREC, Vote Solar, NCSC, and NNEC, 2012) for net metering and interconnection standards. As can be seen, installed capacity has increased over time, as has the number of states with good “grades” on net metering and interconnection polices and with RPS in place, while installed costs of GPV have greatly declined. The number of states receiving “A”s or “B”s on net metering has increased from twelve to thirty-three since 2007; the number of states receiving “A”s or “B”s on interconnection polices has increased from two to twenty-six since 2007; the number of states with RPS has increased from eighteen to thirty since 2004, with seventeen states plus D.C. requiring a portion of the RPS be met with solar energy. Over 540 states or utilities offered rebates for customer sited GPV in 2014, a number expected to decline as installed costs decline (IREC & NCSC, 2014).

In sum, since the grid synchronized inverter greatly expanded opportunities for photovoltaic technology, a body of literature has grown to describe the GPV market and technical and non-technical barriers to GPV. Industry and academic literature from this perspective has focused on legal, institutional and financial barriers. Further, policy and programs to date have largely been based on market based solutions founded in this perspective. It is apparent that such policies and programs have supported an expanded market, but in ways that have not been thoroughly evaluated, and that more opportunities remain in a better understanding of the needs, experiences, and priorities of the product end-users/potential adopters. No “top-down” literature was found that focused on program evaluation or educational campaigns. Such strategies are, however, discussed in adopter-focused research.

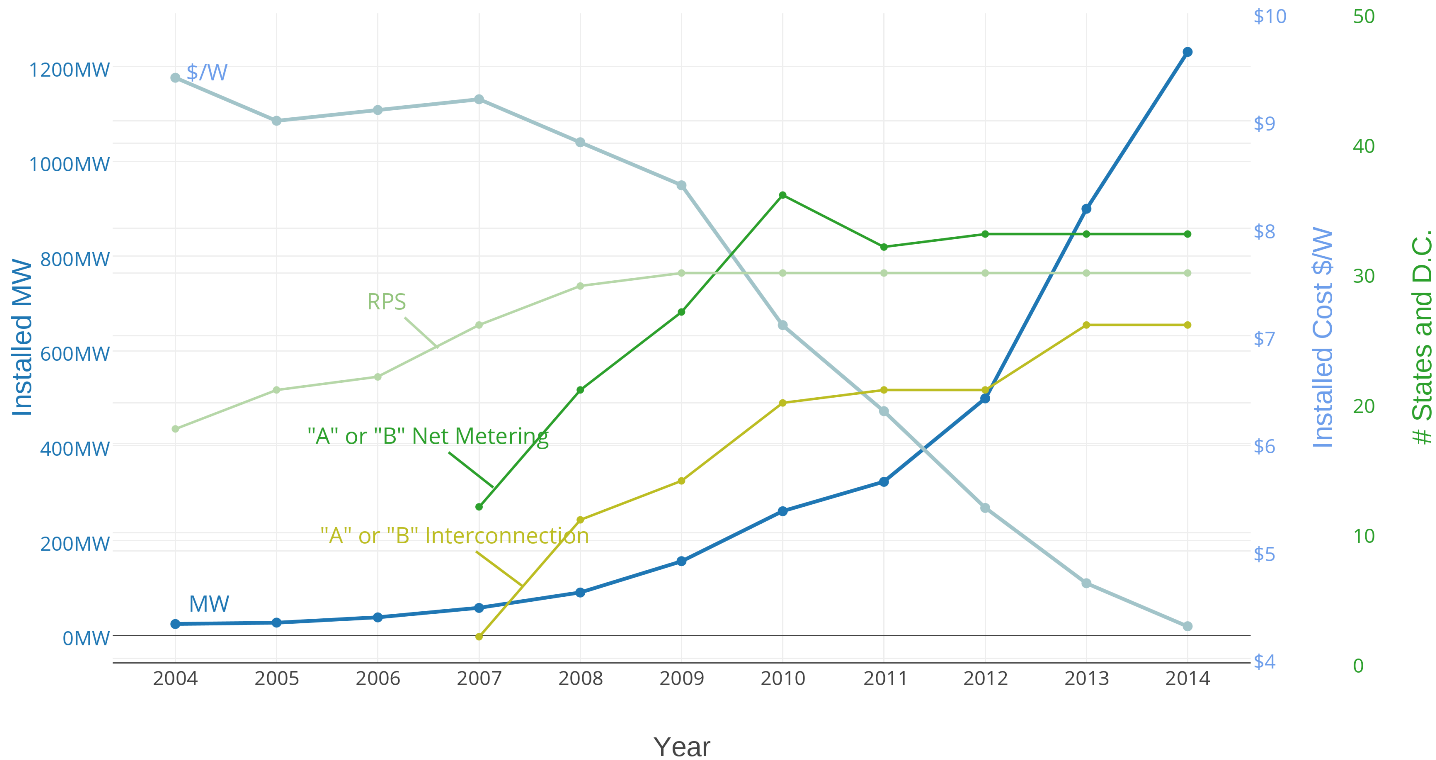


Figure 1. *U.S. Residential GPV Installation Capacity (MW), Installed Cost ($/W), and Policy Trends (# States with Renewable Portfolio Standards, grade of "A" or "B" for Net Metering, and/or Interconnection Standards)*

2.2 Adopter-Focused Research: Rational Choice, Behavioral Economics, Diffusion of Innovations, and Social Marketing Theories

Shama (1981) (see also Hirshberg & Schoen, 1974; Velayudham, 2003) warns of relying too heavily on "macro-level, techno-economic[6] approach to energy policy that disregards "both the micro-level and behavioral aspects" of energy choices (p. 705). In other words, it is important to study the human dimensions of energy technology adoption at the individual level and through social networks, rather than simply relying on high level economic and policy trends and analyses. Research gauging end user motivations for, or barriers to, adoption of GPV and related technologies, tends to be based in rational choice, behavioral economics, diffusion of innovations, or social marketing theory.

2.2.1 Rational Choice Theory

The majority of policy initiatives, guided by "top-down" analyses, are aimed at bringing down the financial cost of GPV, directly and indirectly. The underlying assumption is that people will adopt GPV if the financial cost is low enough. The explicit or implicit theory behind this approach is rational choice theory, which assumes that in a perfect market with free exchange and adequate information, a rational consumer will seek to maximize utility and minimize costs (Gillingham, Newell, & Palmer, 2009). According to rational choice theory, when deciding whether or not to invest in GPV, a fully informed rational actor will weigh the "initial capital cost against the expected future savings" (Gillingham, Newell, & Palmer, 2009, pg. 3), and will invest when the present value of future energy savings (positive net future cash flows)

[6] Techno-economic analysis is a method for evaluating the economic viability of particular technologies in development. Engineering and process modeling is combined with economic modeling (Wallace, 2011).

exceeds the investment. Strategies aimed at reducing GPV costs should bring costs down enough to encourage the rational consumer to invest.

Several authors document a phenomenon that challenges rational choice theorists in the area of energy efficiency investment and may also be relevant to PV investment: consumers consistently fail to invest in cost effective energy efficiency measures. Dubbed the "efficiency gap," rational choice and "non-rational" choice theorists have attempted to explain the consistent lack of customer investment in energy efficiency measures that would yield economic savings (Dyner & Franco,2004; Gillingham, Newell, & Palmer, 2009; Howarth and Sanstad, 1995; Jaffe & Stavins, 1994a, b). Rational choice theorists explain the efficiency gap as resulting from: failures of the market such as environmental externalities or inadequate information (Howarth, Haddad, & Paton, 2000; Jaffe & Stavins, 1994a,b); or high discount rates[7] (Gillingham, Newell, & Palmer, 2009; Houston, 1983; Howarth & Sanstad, 1995) placed on the investment by consumers. Rational choice theorists claim such high discount rates could be rational given unknowns about investments risks and future costs savings (Jaffe, Newell, & Stavins, 2004; Sutherland, 1991), or the fact that that waiting to invest could be more advantageous than present investment (Hassett & Metcalf, 1993).

GPV systems historically have had higher initial capital costs than other energy efficiency measures. Although installed costs have dropped substantially, Barbose and Dargouth (2015a) document important geographic variability in installed costs, as influenced by the structural barriers discussed above, including industry, local government, and utility experience and

[7] The discount rate refers to the interest rate used in to determine the present value of future cash flows, taking into account the time value of money, and the uncertainty of future cash flows (Investopedia, 2016).

support. Return on investment and payback time is also impacted by locally variable conditions such as utility buyback rates. These factors combined with individual circumstances such as available roof space and orientation contribute to variability in the cost effectiveness of GPV.

Generally, however, the economics of GPV are improving across the board. The lack of adoption in areas where economics are more favorable, and the adoption by others where the economics are not favorable points to non-economic based factors relevant to adoption. Geographic variation in GPV adoption has been explained primarily through top-down market based analysis, grounded in the rational choice perspective (Barbose, 2014; Kwan, 2012). Behavioral economics, Diffusion of Innovations, and social marketing theories (see below) emphasize the relevance of non-cost factors in addition to cost factors, and the importance of understanding end-user perspectives and characteristics in explaining the adoption process.

2.2.2 Behavioral Economics

Non-rational behavior is considered by several researchers to be an important factor in explaining the efficiency gap (Dyner & Franco, 2004; Shogren & Taylor, 2008; Zundel & Stieb, 2011), and other purchase decisions. Behavioral economics “explores, catalogues, and rationalizes systematic deviations from rational choice theory.” (Shogren & Taylor, 2008, p.26) Key concepts of behavioral economics include “bounded rationality,” “bounded willpower,” and “bounded self-interest” (Shogren & Taylor, 2008, p.26). Collectively, such concepts are referred to as “behavioral failures” (Gillingham, Newell, & Palmer, 2009, p.8; Shogren & Taylor, 2008, p.27), paralleling the notion of market failures. “Bounded rationality,” is the concept that certain people or groups of people, have limited capacity to process the information needed to make a rational energy investment (Dyner & Franco, 2004; Howarth, Haddad, & Paton, 2000; Shogren & Taylor, 2008). "Bounded willpower," reflects the idea that people sometimes lack self-control (Shogren & Taylor, 2008), making irrational choices regarding energy consumption. Finally, "bounded self-interest" refers to altruistic motivations for investment decisions (Shogren & Taylor, 2008). The purchase of GPV for non-economic motivations such as environmental benefits or energy independence, especially in cases where GPV is not cost efficient, would constitute a behavioral failure according to behavioral economics, as would the decision not to purchase a GPV system where it is cost effective but the consumer is perhaps unclear about one or more cost variables involved, such as utility buyback rates. Both the concepts of "behavioral failures" and "market failures" assume that there is an underinvestment in "socially optimal" levels of energy efficiency and renewable energy (Gillingham, Newell, & Palmer, 2009, p.8). From an economic perspective, it is less clear what the "socially optimal" level of renewable energy, including GPV, investment would be.

Diffusion of innovations (DOI) and social marketing theory/ies explore adoption of technology (and other innovations) and behavior change beyond economic considerations. Like behavioral economics, DOI and social marketing researchers utilize methods to directly assess end user perspectives and experiences, such as surveys, interviews, and focus groups.

2.2.3 Diffusion of Innovations

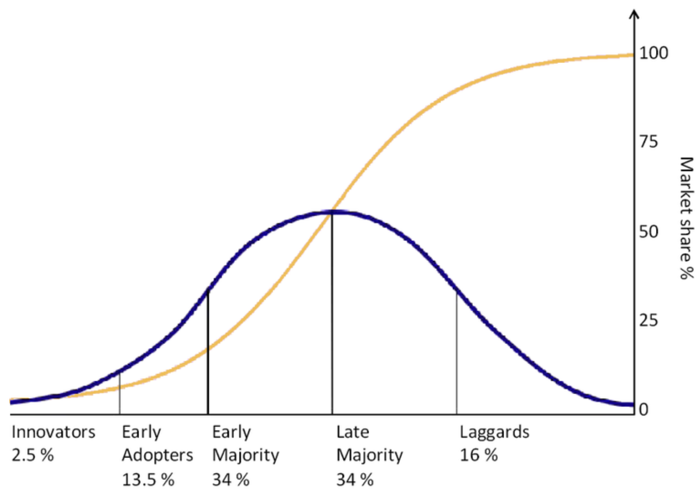
The diffusion of innovations (DOI) theoretical framework, originally developed by Everett M. Rogers in 1962 (Rogers, 2003), describes the process by which an innovative technology or idea is adopted and spread through a social system (Rogers, 2003, p. 11). The process involves an individual's "innovation-decision process," in other words whether or not an individual will adopt an innovation, as well as the "diffusion" or spread of an innovation through a social system.

During the innovation-decision process, an individual or decision-making unit moves through various stages from initial awareness about an innovation to being persuaded to adopt or reject, and finally to sustain or quit its use. This process is described as being primarily an "uncertainty reduction" process (p. 168), where perceived attributes of an innovation such as relative advantage compared to existing or other technologies, compatibility with values and norms, complexity, trialability, and observability (pp. 15-16) are especially important, as are the experiences of "near peers (330)." DOI scholars have found that different sources of information are important at different points along this process.

The diffusion process is described as being more than the sum of individual adoption decisions; it involves the activation of social networks. As an innovation gets communicated among one or more social networks, especially through trusted communication channels and community opinion leaders, the innovation spreads more rapidly. According to DOI, adoption of an innovation follows a predictable S-shaped cumulative diffusion curve (see Figure 2.2), which is flatter in the beginning and ending stages of adoption, but steeper in the middle where social systems have been activated, and adoption rapidly spreads. Adoption is claimed to "take off" after community "opinion leaders" adopt, and a "critical mass of adopters" (between 10 to 20% of individuals in a system) is achieved. After this point, Rogers asserts that diffusion is almost impossible to contain (Rogers, 2003, pp. 274, 300, 343).

DOI research asserts that different categories of people adopt at different points over time as influenced by the setting, their personal attributes, attributes of the innovation, and communication channels. These adopter categories are described in terms of their "innovativeness (p. 22)," with members of each category said to share characteristics and be similarly influenced. "Innovators" are said to represent the first 2.5% of adopters, followed by "early adopters" (13.5%), the "early majority" (34%), the "late majority" (34%), and finally the laggards (16%) (Rogers, 2003).

Figure 2. *Rogers Diffusion of Innovations Curve over Time*



Note: Blue is non-cumulative adoption; Yellow is cumulative.
Source: Image from Wikipedia. 1.12.12 (Rogers, 2003).

Rogers presents several "generalizations" about socioeconomic variables, personality traits and communication behavior as differentiated between adopter categories (Rogers, 2003, pp. 287-291). These are presented here, because many of these generalizations are supported by the adopter focused GPV research, and are evaluated as a part of this study for relevance in the Solarize Plano case study and for future program design. The order presented below reflects anticipated relevance based on GPV specific literature presented later in this chapter.

According to Rogers, DOI research across innovations has consistently found compared to later adopters, earlier adopters:

- Have more years of formal education
- Have higher socioeconomic status
- Have larger sized units (houses, farms, companies, etc.)
- Are no different in age
- Have a more favorable attitude towards change
- Are better able to cope with uncertainty and risk
- Have a more favorable attitude towards science
- Have more social participation
- Are more highly interconnected through interpersonal networks
- Seek information about innovations
- Heave greater knowledge of innovations
- Have a greater ability to deal with abstractions
- Have greater rationality
- Have more intelligence
- Have more contact with change agents
- Have greater exposure to mass media communications
- Have greater exposure to interpersonal communications
- Have greater empathy
- Are less dogmatic
- Have higher aspirations (education, status, occupations, etc.)

- Are more cosmopolitan, and
- Have a higher degree of opinion leadership.

In the most recent publication of *Diffusion of Innovations* (2003), Rogers summarizes themes or conditions that appear to have facilitated widespread, rapid, and sustainable diffusion of a variety of innovations in a variety of settings:

The *innovation:*

- is perceived to be:
  - relatively advantageous compared to existing technologies it would replace;
  - compatible with the social system's norms, and the needs of individuals within the system; and
  - not complex;
- can be used on a trial basis before full adoption, and
- results of the innovation can be observed prior to adoption.

The *community*:

- has easily identifiable social networks, with opinion leaders whom are open to innovation and supportive of the proposed innovation;
- has had favorable experiences with other similar technologies;

The *change agency*, or the group seeking to promote adoption:

- takes great care to make sure the innovation is compatible with the community;
- involves stakeholders in shaping the outreach campaign;
- ensures quality experiences with the innovation among opinion leaders; and

- measures program success not simply in terms of adoption totals, but in terms of sustained and “quality” adoption.

The vast majority of academic literature focusing on adopter characteristics, motivations, perceptions, and barriers to adoption of PV and similar technologies, is grounded in the DOI framework, including research by Barbara C. Farhar (Farhar & Buhrmann, 1998, Farhar & Coburn 2006), Faiers & Neame (2006), Labay & Kinear (1981), Rai & Robison (2013), Rai &McAndrews (2012), Sidiras & Koukios (2004), and Velayudham (2003). The literature points to important differences in factors influencing adoption for adopters/end –users and other stakeholders (utilities, government, industry) as well as among “categories” of adopters themselves (innovators, the early majority, etc.) (Faiers & Neame, 2006; Faiers, Neame, & Cook, 2007; Labay & Kinnear, 1981). This underscores the importance of studying end-users, their perceptions and their experiences in each context, over time.

While the DOI framework presented by Rogers provides a useful foundation for understanding concepts relevant to a community PV promotion campaign, there are some important limitations. First, the shape of the diffusion of innovations curve can only be assumed to be normal (or S-shaped cumulatively) for innovations where 100% diffusion is possible (Rogers, 2003, p. 281). For innovations such as GPV, where 100% adoption is not possible nor even advisable, the ability to describe, predict, or effectively set goals based on categorization of adopter type or by the potential relevance of innovation attributes is more difficult, as would be achieving the “critical mass” (10-20%) necessary to trigger more widespread adoption where this is the goal. The DOI framework provides a reference point, but not a complete toolkit for actually facilitating adoption of GPV in a community.

2.2.4 Social Marketing

The Social Marketing perspective, considered by Rogers to be a member of the Diffusion of Innovations tradition, suggests comprehensive and practical approaches for implementing behavior change programs in a community. The community based social marketing approach utilizes strategies from the field of consumer marketing, grounded in social psychology and behavior change research (McKenzie-Mohr & Smith, 1999), to foster sustainable behavior/s in a target community. The key in effecting the desired behavior change is to thoroughly understand the target audience (formative research described by Rogers), especially perceived barriers and benefits to the desired behavior (similar to Rogers' perceived relative advantage), and to design a program that specifically addresses these perceived barriers and benefits (Rogers' compatibility and change agent effectiveness). Audience research plays a particularly important role in social marketing, with focus groups used as a primary tool. Special emphasis is placed on studying both those who participate in the desired behavior, and those who do not.

Efforts to better understand local perceptions of PV through surveys and focus groups by the cities of Berkeley, Orlando, Portland, San Diego, and Tucson have generally followed the social marketing perspective. By encouraging identification of audience specific concepts and the design of programs around those concepts, the social marketing approach offers practical methods for promoting GPV in a community. However, the question remains whether the one time purchase of a GPV system fits the overall the social marketing/behavior change theoretical model aimed at creating sustained behavior change. Key concepts emerging from the DOI and social marketing literature describing the characteristics of GPV adopters/potential adopters, and the benefits, barriers and motivations for adopting GPV from an adopter perspective will be summarized below.

2.2.5 Adopters and Adopter Perspectives: Characteristics, Benefits, Barriers and Motivations for GPV Adoption

The adopter-centered research reviewed largely employs inductive qualitative interviews and/or deductive quantitative survey based methods to study barriers, perceptions, motivations, and socio-demographic trends among adopters, and non-adopters from their perspective.

Qualitative studies (Farhar & Burman, 1998; Farhar-Pilgrim & Unseld, 1982; Jack Lambert, 2010; McEachern & Hanson, 2008), where “data” emerges from the participants themselves, provide substantially more detail and nuance to identified barriers and motivations. Survey designs are often structured to gauge consistency among adopters/non adopters with Rogers’ concepts, including desired product attributes such as simplicity, compatibility with values and norms, observability, and triability (the ability to “try out” the product in advance); information sources; and adopter (especially early adopter) characteristics, such as level of education, income, and comfort with trying new things (Faiers & Neame, 2006; Faiers, Neame, & Cook, 2007; Labay & Kinnear, 1981; McEachern & Hanson, 2008; Rai & McAndrews, 2012; Rai & Robinson, 2013; Peter, Dickie, & Peter, 2006; Velayudham, 2003).

Several surveys are designed to gauge concepts relevant to particular communities, in line with social marketing (City of Berkeley 2008; City of San Diego, CCSE, & USDOE, 2009; City of Tucson staff, personal communication, May 2009; SmartPower, 2007). The most recent adopter-centered research, and perhaps most relevant to this study, has been published by Varun Rai and researchers from the University of Texas at Austin (Rai & McAndews, 2012; Rai & Robinson, 2013). Rai, McAndrews and Robinson analyze a survey dataset composed of PV adopters in north and central Texas, looking for socio-demographic trends and motivations and barriers to PV adoption, as well as details on the decision time period.

Labay and Kinnear (1981) and Faiers and Neame (2006), found that perceptions of PV vary between adopters and potential adopters or non-adopters. Potential adopters found PV to be more risky, complex, less affordable, less attractive, and less compatible with their norms than adopters. They also perceived payback to be less favorable and available grants or incentives to be insufficient. Rai and Robinson (2013) found that Texas PV adopters had on average about 50% higher median income and tended to be more educated (80% versus 25.4% held a Bachelor's degree or higher) than the average Texan. Across many studies, adopters exemplify several of Rogers' early adopter characteristics such as altruism (Jack Lambert, 2010), leadership (Farhar & Burman, 1998; Jack Lambert, 2010; SmartPower, 2007), a desire to teach others (Farhar & Burman, 1998; Jack Lambert, 2010), and to do the right thing (Farhar & Burman, 1998; Jack Lambert, 2010). These early adopter characteristics are not mentioned in the recent studies by Rai et al., but perhaps this is due to the use of survey rather than interview methodology, where concepts are presented to be tested rather than emerging from participants.

Financial aspects, including high initial cost (City of Tucson staff, personal communication, May 2009; City of Berkeley, 2008; Farhar & Burman, 1998; Faiers & Neame, 2006; Faiers, Neame, & Cook, 2007; Jack Lambert, 2010), lack of good financing (Peter, Dickie, & Peter, 2006; Prasad, 2008), concern and confusion over utility buyback rates (Farhar & Burman, 1998; Jack Lambert, 2010), and concern about the impact on home resale (Farhar & Burman, 1998; Jack Lambert, 2010), were mentioned as a barrier in all studies, with a few studies indicating adopters hoped that PV would reduce risks of increasing electricity prices (Labay & Kinnear, 1981; Rai & McAndrews, 2012; Sidiras & Koukios, 2004). Incentives and rebates are also mentioned as imperative in several studies (City of Tucson staff, personal communication, May 2009; Faiers & Neame, 2006; Faiers, Neame, &Cook, 2007; Farhar & Burman, 1998; Labay & Kinnear, 1981; Jack Lambert, 2010; Peter, Dickie, & Peter, 2006; Velayudham, 2003). The notion of PV as a “prudent” investment emerges only in the most recent research (Rai and McAndrews, 2012). Product durability and performance is also mentioned as an important factor across studies (Faiers & Neame, 2006; Faiers, Neame, & Cook, 2007; Farhar & Burman, 1998; Labay & Kinnear, 1981; Prasad, 2008; L. Rosoff, personal communication June 17, 2009).

Confusion about the technology and the overall process (from research to purchase and installation) as well as difficulty of the overall process, are also consistent themes (Faiers & Neame, 2006; Faiers, Neame, & Cook, 2007; Labay & Kinnear, 1981). Lack of information was cited as a problem in earlier research (City of Tucson staff, personal communication, May 2009; Farhar & Buhrman 1998; Peter, Dickie, & Peter, 2009), whereas more recent studies point to the difficulty in wading through abundant information (City of Berkeley, 2008; Rai & McAndrews 2012; Rai & Robinson, 2013) and the desire for trusted sources of information (Jack Lambert, 2010; Rai & Robinson, 2013).

Motivations for installing PV mentioned across adopter focused studies include: energy independence and self-sufficiency (Farhar & Buhrman, 1998; Jack Lambert, 2010; L. Rosoff, personal communication June 17, 2009; Sidiras & Koukios, 2004), concern for the environment (Faiers & Neame, 2006; Farhar & Buhrman, 1998; Jack Lambert, 2010; Rai & McAndews, 2012; Rai & Robinson, 2013; Sidiras & Koukios, 2004), and specifically the desire to think globally but act locally (Farhar & Buhrman, 1998; Jack Lambert, 2010) and have less reliance on polluting forms of energy (Farhar & Buhrman, 1998; Jack Lambert, 2010; Sidiras & Koukios, 2004). The qualitative adopter studies indicate that values such as trust and reliability in the installer, the technology, and the utilities are very important (Farhar & Burman, 1998; Jack Lambert, 2010).

2.2.6 Geospatial Studies on Factors Influencing PV Adoption

One study reviewed utilizes census data to infer importance about variables of interest on adoption (Kwan, 2012). The census based study tested the significance of the following variables on household PV adoption, using zip-code level data: solar insolation, cost of electricity, available financial incentives, median household income, median home value, race, age, education, housing density, urbanization, part membership, city membership in ICLEI-Local Governments for Sustainability. Solar insolation, cost of electricity, and available financial incentives were found to be statistically important factors influencing residential PV adoption.

McEachern and Hanson (2008) attempt to synthesize findings from a geo-spatial analysis of village level variation in household PV adoption in Sri Lanka, with factors identified through individual qualitative interviews of individuals. Important findings from this analysis include the role of social and cultural factors that may vary geographically, to individual adopters. McEachern and Hanson find, in line with Rogers, that trusted community opinion leaders are very important to PV adoption among Sri Lanka villagers. Specifically, whether or not a village priest or religious center had installed a PV system, is found to be very important to adopters in Sri Lanka. This would be an interesting concept to test in the U.S., including areas with higher than average religiosity.

2.3 Synthesizing "Top down" and End User Perspectives on GPV Adoption

The literature reveals certain repeating themes in both the top-down technical literature and the adopter-focused literature relevant to adoption of solar energy systems. On the whole, adopter centered research compliments "top down" research, rather than conflicting with its findings or recommendations, and generally provides more detailed or additional information on potential barriers and motivations to end users. Both perspectives offer a theoretical and conceptual reference, as well as methodological considerations, for studying GPV adoption in the DFW region. Concepts repeated across studies and common to both adopter-focused research and expert, or "top-down" research, such as policy or macroeconomic analyses, are presented in Table 3 below.

Table 3. *Factors Influencing GPV Adoption: "Top-down" and Adopter Perspectives*

Top Down Perspective		End-User/Adopter Perspective	
Technical			
Panel/component Efficiency	33	Performance/Trust	9,10,19,26,29
Panel/component Durability	33	Durability	10
Demand management	1,12,13,1	Complexity/lack of technical understanding	10,19,30
Grid integration	14,20,22,32	Warranties	10,16
Safety	15,36	Safety	10
Structural or Legal			
Interconnection policy (+/-)	15,24,35	Trust in Utility	10,16
Permitting: complexity, expense, consistency	1,6,15,24,35	Time/confusion over inspections	16
Net metering policy (+/-)	3,4,15,35	Trust/lack of clarity from Electric Service Provider	10,16
Planning and Zoning	24,36	HOA	16
RPS	3,35	Legal/regulatory uncertainties	10,30
Financial			
High Initial Cost	2,11,24,32,36	High Initial Cost	8,9,10,16,25,
Financing	2,24,32,36	Financing	23,26
Rebates/Incentives	36	Rebates/Incentives	8,9,10,16,18,19,23,37
No fuel costs	33	Unclarity for estimating savings	28
Buyback rates (also legal)	3,15,36	Buyback rates (also legal)	4,10,16
		Payback	10,16,30
		Reduced future energy cost	19, 30,37
		Cost of electricity	18
		Financial Implications of home sale	10
Information			
Lack of costumer awareness/knowledge	32	Information sources- trust	10,21,23,26,27,37
		Lack/Confusing/conflicting information	10,35
		Trust	23,25,27,28,30,37
Installer/Workforce			
Need for training	15,32	Informed	16,18
		Trust	10,16,18
Environment			
Low impact	5,34,36	Low impact	8,9,10,16,37
		Desire to lead by example	10,16
Energy Independence			
Domestic Energy Source	5,36	Domestic Energy Source	10,16
		Independence from utility	29
		Power when storms	10,37
		Self-sufficiency	10,16,29
Other			
		Maintenance Aesthetics	8,9,10
		Friends/Neighbors/Others	10,21,27,30,37
		Interest in RE/Curiosity	10,16
		Responsibility or Leadership	10,16,19, 31
		Ease/difficulty of overall process	8,9,19,29,30

1 Alajlan, 1999
2 Ardani et al., 2013
3 Barbose & Darghouth 2015a
4 Barnes & Vernado, 2010
5 Berman & O'Connor, 1996
6 Brooks, 2012
7 City of San Diego, CSE, USDOE,2009
8 Faiers &Neame, 2006
9 Faiers, Neame, & Cook, 2007
10 Farhar & Buhrman, 1998
11 Friedman et al., 2013
12 Hill, 1994
13 Hoff and Shugar, 1995
14 Garve, Latour, & Sonvilla, 2012
15 See all *Freeing the Grid* reports for years 2007-2014 1st author: IREC or NNEC
16 Jack Lambert, 2010
17 Kind, 2013
18 Kwan, 2012
19 Labay & Kinnear, 1981
20 Lindt, Fox, Ellis, & Broderick, 2013
21 McEachern &Hanson, 2008
22 Paidipati et al. , 2008
23 Peter, Dickie, & Peter, 2006
24 Pitt, 2008
25 City of Tucson staff, personal communication, 2009
26 Prasad, 2008
27 Rai & McAndrews, 2012
28 Rai & Robinson, 2013
29 L. Rosoff, personal communication, 2009
30 Sidiras & Koukios, 2004
31 SmartPower, 2007
32 Solar Electric Power, 2001
34 Stanfield & Vanega, 2015
34 Sterzinger & Svrcek, 2005
35 USDOE, 2010
36 USEPA, 2016
37 Velayudham, 2003
38 Wesoff, 2014

Unfortunately, research on consumer/adopter experiences, perceptions, and attitudes regarding GPV is very limited for the U.S. and appears to be non-existent for the DFW region, as is research evaluating the effectiveness of existing or proposed initiatives in addressing barriers and meeting consumer needs. The Diffusion of Innovations and social marketing research consistently finds that programs or strategies promoting adoption of a technology or energy saving behavior, without proper consideration of the local context and the factors important to potential adopters, fail to be effective. Additionally, the importance of adopter-centric research in explaining and addressing geographic and socio-economic nuances in adoption has become clear.

Clarifying the regional solar landscape, and exploring, comparing, and synthesizing concepts identified by local residents with those identified by in the literature, will provide data relevant to GPV development in the DFW region. Drawing from approaches in several studies reviewed, this dissertation employs a mixed methods design to better understand the status of GPV adoption in DFW and those factors influencing adoption. Basic GPV adoption metrics, including distribution and socio-demographic information at the various scales of interest are presented (Chapter 3). Inductive qualitative methods are used to gain in depth understanding of the factors relevant to local adopters and potential adopters of GPV from their perspective, using the Solarize Plano model as a case study (Chapter 4). In line with DOI and social marketing research, information is gathered on adopter and potential adopter characteristics and values, desired product and provider attributes, preferred information content and channels, perceived barriers and general experience with the process of deciding whether or not to purchase GPV. Themes presented in the literature will be explored for local relevance.

Perspectives and experiences of Solarize Plano program participants, organizers, and selected installers, will also be used to evaluate success of the Solarize model in overcoming barriers to GPV adoption. As a result, this dissertation utilizes the Solarize Plano program as an opportunity to learn about nuanced and contextual factors that encourage or discourage residential GPV adoption in Plano, and perhaps across the region; to evaluate success of this model in overcoming barriers; and to extract lessons pertinent to regional GPV adoption.

CHAPTER 3

GRID-CONNECTED PV METRICS

3.1 Overview

This study provides information pertinent to GPV market development in North Central Texas and utilizes the Solarize Plano project as a case study with regional relevance. In order to study the influence of various factors, including those that are context specific, on GPV adoption one must understand the “lay of the land,” or the history and the current status of a variety of basic measures on GPV installation and other relevant factors. Specifically, before one studies why a homeowner has installed or not installed a GPV system, or looks for trends among homeowners and how those trends vary with geographic location and scale, it is useful to have this baseline. Important questions include: How many systems have been installed in the area? Where and when were they installed and by whom? How much do these systems cost and how has that changed over time? What electric utilities or government agencies have offered GPV incentives and how have these changed over time? What other information is known about the area that could influence adoption, as indicated by the literature? This chapter provides answers to many of these questions using the best available data and sources.

The objectives of this chapter are:

1) to summarize for the study area all known metrics on residential GPV installations including numbers, size (in kW_{DC}), and cost by location over time;
2) to summarize for the study area available information on factors identified in the literature that could influence adoption including:
    a. select socio-demographic variables and, where available,

    b. utility and government incentives and policies or procedures;

3) to compare measures within the region to measures for Texas and the U.S., over time;
4) to identify trends and other areas of interest such as locations with relatively high or low adoption;
5) where possible, to connect trends in installation numbers to trends regarding socio-demographics and/or utility information; and,
6) to identify holes in the data and make recommendations for future data collection and research.

As indicated by the literature, information is often lacking for basic installation measures, especially at a finer geographic resolution, and for context specific factors influencing adoption. This chapter summarizes the best available data on GPV installations for the study area and presents it alongside similar metrics for Texas and the U.S. for comparison. Tracking and comparing metrics at each scale, especially when enriched with qualitative data, helps to identify where policy and programmatic assumptions are in line with real world dynamics, where assumptions may be misguided, and how policy and programs could be more effective.

Many of the installation metrics and regional trends presented in this section have not been previously compiled and the presentation here aims to provide a baseline for regional study over time, as well as a reference point for analyzing the connection between concepts identified in the qualitative analysis, and quantitative installation trends. In addition, holes in the data and recommendations for further work and research are identified. Chapter 4 then provides an in depth study of factors influencing adoption in the Plano area among Solarize

Plano program participants, with the goal of evaluating the program's effectiveness and identifying lessons that might be transferrable to the region in general.

3.2 Study Boundaries: Geographic Boundaries for Data Study Time Frame

The geographic boundaries of the 16 county NCTCOG, and the 169 cities represented, define the information summarized, calculated or estimated for DFW region. Of the 169 city members of NCTCOG, 82 cities reported having one or more residential GPV system installed (see section 3.3.1.3), and 67 of those have a population of 5,000 or more.

Data and trends included in this study cover the time frame of 2008-2014. This time frame was chosen because it is broad enough to include the first permitted GPV system in Plano, includes the complete cycle for the Solarize Plano project, and data are available for most metrics across all scales of interest. Ten systems were permitted and installed in DFW prior to the study timeframe, with the first permitted system installed in DFW in 2004. While most figures, tables, and analyses include only data since 2008, the ten systems installed prior to 2008 are included in cumulative DFW regional installation figures (section 3.5.2).

3.3 Data Sources and Methods

Three basic categories of data are needed to answer the questions asked in section 3.1: basic information on the actual GPV systems; socio demographic information; and details on utility and or government programs, policies and procedures specific to the region. Some of this information was readily accessible and required only summarizing existing published data, while other information, especially for the study area, required secondary analysis of existing data sets or primary research. Information was not available to thoroughly answer all questions, and this will be further described below.

3.3.1 Basic Installation Metrics

How many systems have been installed? Where and when? What was the installed cost over time? For the state and federal levels, information to answer these questions was readily available in published reports, or or obtainable directly from the authors, for most of the study period, 2008-2014. Data sources and basic methods and assumptions are described in section 3.3.1.2, below. Answering these questions for the DFW region and for the city of Plano, required both secondary analysis of existing datasets, and primary research, as described in section 3.3.1.3, below.

3.3.1.2. U.S. and Texas Texas Installation Metrics

Data on basic installation metrics for the U.S. and Texas, for 2008-2014, came from three widely referenced series of reports, and from follow up communications with their authors. Since 2009, the Interstate Renewable Energy Council has produced annual "U.S. Solar Market Trends" reports authored by Larry Sherwood. These reports present publically available data on total annual and cumulative PV installation numbers and capacity by market segment for the U.S. and leading states, as well as metrics on other solar energy (non PV) technologies. Data used in these reports are obtained from state agencies and organizations administering incentive programs, utility companies that manage incentive programs and/or interconnection agreements, and some non-profit organizations. Installation numbers are considered fairly accurate as originally reported. Capacity is presented in DC Watts under standard testing conditions ($W_{DC\text{-}STC}$). When capacity is not originally reported in $W_{DC\text{-}STC}$, a conversion factor provided by the California Solar Initiative is used to translate original data into the equivalent of $W_{DC\text{-}STC}$. Installation dates largely reflect the date of interconnection as reported by utilities, but in some cases reflect the date of incentive payment. Data sources and assumptions are described in detail in Appendices A and B for all reports (Sherwood 2009, 2010, 2011, 2012, 2013, 2014).

Beginning with the 2011 “U.S. Solar Market Trends” report, IREC began collaborating with GreenTech Media, a private market research firm, and the Solar Energy Industries Association (GTM/SEIA, 2011) to produce these reports. The GTM/SEIA partnership compiles detailed quarterly market data (Sherwood, 2011, p.18). IREC’s final annual report was published in 2014 (2013 data), at which time GTM/SEIA continued to publish quarterly and annual solar market reports in print and online. GTM/SEIA prepares detailed market analyses, available for a fee, that contain much of the data previously available in the IREC reports. Summary data are published free of charge in newsletters and print. Senior staff for the Solar Energy Industries Association provided 2014 data for several metrics (SEIA staff, personal communication, September 25, 2015) for this study.

Lawrence Berkeley National Laboratory began publishing the “Tracking the Sun” series on “Installed Costs of Photovoltaics in the U.S.,” in 2009 (Wiser, Barbose, Peterman, & Darghouth, 2009; Barbose, Darghouth, & Wiser, 2010; Barbose, Darghouth, Wiser, & Seel, 2011; Barbose, Darghouth, & Wiser, 2012; Barbose, Darghouth, Weaver, & Wiser, 2013; Barbose, Weaver, & Darghouth, 2014; Barbose & Dargouth, 2015a).” These reports present state and aggregate information on pre-incentive installed costs for residential and non-residential PV systems beginning in 1998. Cost trends are based on sample data that has become more geographically representative over time, and is segregated by system size and market segment. Methods are detailed in each report. These reports use the median installed price in $\$/W_{DC\text{-}STC,}$ which is calculated based on the price paid to the installer or project developer before any incentives (direct incentives usually issued by utilities and/or tax incentives) are applied (Barbose, Weaver, & Darghouth, 2014, p.1).

3.3.1.3. DFW Region and Plano Installation Metrics

Summarizing the number, size, installation dates and locations, and installed costs over time for the study area, in a manner that is internally consistent with the data for other scales, presented a challenge. As described in detail below, the most complete information on basic PV metrics are maintained by transmission and utility distribution utilities who manage interconnection, and also by programs that aggregate these data; however, such data are not accessible for the study area. The best available data on residential GPV systems for the NCTCOG region and the City of Plano, are two datasets composed of city permit information. These datasets required both secondary analysis, and primary research, to extract data to meet the objectives outlined in section 3.1. The major limitations of the data are the absence of: system size (in kW_{DC}), accurate installed costs, and installation dates. This section describes the data sources and methods for data refinement and assumptions, including preliminary analysis required to adjust listed permit dates in some records to reflect actual installation dates.

3.3.1.3.1 Utility and Aggregate Data

The most accurate and complete source of installation metrics are the transmission and distribution utilities, or state and national databases that aggregate such data. The National Renewable Energy Laboratory (NREL) maintains the Open PV project, a database summarizing information on installed PV capacity across the nation, as "voluntarily contributed from a variety of sources including utilities, installers, and the general public (NREL, n.d.)." Open PV includes data on installed capacity, date, cost, and location (by zip code or physical address), for individual systems, and is an excellent resource for PV installation metrics and distribution across the U.S. Unfortunately, consistency in reporting to Open PV varies from location to location, and reporting has not been consistent for the DFW region. Oncor, the primary transmission and distribution utility in the DFW area, provided data on customer GPV installations to the Open PV project until early 2013 when they stopped reporting due to customer privacy concerns (Solarize Plano organizer, personal communication, July 1, 2015).

Oncor continues to keep most installation data private (Senior Oncor Staff, personal communication, October 18, 2015). In fact, several utilities in Texas are currently citing privacy considerations in their fight against state efforts to require reporting of basic GPV installation data (Plano Solar Advocates volunteer, personal communication, October 22, 2015). The State of Texas requires investor-owned utilities to report annually on distributed generation by customer class for their service territories (Oncor Rates and Regularly staff, personal communication, March 4, 2016); however, it is not possible to break these numbers down geographically by NCTCOG cities or counties.[8]

3.3.1.3.2 Building Permit Data

Currently, the most accessible and complete source of installation data for the study area, including the NCTCOG region and the city of Plano, is building permit data maintained by municipal building inspections departments. Database summaries of publically available permit data, including permit number, permit "date" (see below), permit status, permit type (residential or commercial), applicant name, installation address, reported cost, installer, and property details, have been compiled and provided by two individuals from the region, Jay Squyres and Richard "Larry" Howe. Squyres and Howe are both members of the North Texas Renewable Energy Group (the North Texas chapter of the non-profit Texas Solar Energy Society). These databases, with some adjustments described below, serve as a solid source for regional and case study data on the number, location, and installation date of residential GPV systems.

The DFW solar permit database was assembled and provided by Jay Squyres. In response to the gap in centralized data on regional PV installations, Squyres made public records requests "to all 23 cities in the NCTCOG Solar Ready II project, and 100 other cities in the 16 county area" (Squyres, 2014). NCTCOG represents 169 municipalities plus 22 school

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[8] Installation numbers are available for interconnected residential systems in Oncor territory, as reported in ERCOT"s annual load profiles (ERCOT 2016). However, the finest geographic level that these numbers can be broken into is by weather zone. Oncor's North Central Weather Zone consists of 32 counties, including the 16 NCTCOG counties, and there is no way to accurately attribute systems listed in a weather zone to the actual cities or counties in which they are installed (Nelson 2016). Using population as a reference, 93% of Oncor's North Central Weather zone population is concentrated in the NCTCOG counties.

districts and 31 special districts. Squyres' dataset contains PV permit records from 82 of the 169 NCTCOG municipalities. It is assumed that these represent all of the permitted installations for the study area and time frame. Any error would be attributed to permit processing or clerical errors, or with failure of the PV system owner or installer to apply for a permit. Potential for this error was not possible to quantify and is assumed to be low.

Richard "Larry" Howe, a solar advocate with GPV installed at his residence, similarly compiled a database of all PV systems installed in Plano, Texas. Records were obtained through a public records request to the City of Plano Building Inspections Department.

As described below, the same procedures were applied to both the Plano and DFW databases as a part of this study, in order to separate residential from non-residential systems, to omit erroneous records, and to best estimate system installation dates. Erroneous permit records include: duplicate records, records for PV systems not actually installed, and records for non-PV permits that were included in the original list. Both original datasets contained a few records where multiple permit applications had been submitted for a single PV installation by the same or different installer. Also permits obtained for electrical upgrades associated with a PV installation were sometimes originally included.

For both the DFW and Plano datasets, records were first sorted by "type" to separate residential from commercial or other non-residential installations. Records with permit status listed as "expired," "cancelled," "withdrawn," or "void," were deleted. Permit data were then sorted by address. For residential systems where multiple records/permits were pulled for the same address, PV installers listed on permit records were first contacted to properly classify the installations as new or system additions (considered new installations), updated applications, or erroneous entries. When installers could not be reached, city building permit officials were contacted to review the records. When neither installer nor permit official could definitively classify permit data for duplicated addresses, those with "date" entries separated by more than 1 year were considered additions after installation was confirmed via satellite imagery on Google maps. Installers and permit officials also clarified likely installation years, for those systems with no final inspection listed (see section 3.3.1.3.2.1 below). Table 4 summarizes the original records contained in DFW and Plano databases, and final number of records used for this study, after filtering, sorting, and omitting erroneous records.

Table 4. *PV Permit Records Summary for DFW and Plano, 2004-2015*

	DFW	**Plano**
ORIGINAL TOTAL permitted PV systems/records	2166	223
ORIGINAL Residential systems/records	1930	206
ORIGINAL Non Res	236	17
Minus duplicate records errors	24	2
Minus expired, withdrawn, void	53	8
Other error (not NCTCOG, no GM, missing records)	2	1
FINAL TOTAL ALL PERMITTED PV	2087	214
FINAL TOTAL RES 2004-2015*	1853*	199
FINAL TOTAL NON RES2 2004-2015*	234	15
FINAL TOTAL RES 2004-2014	1839*	190
FINAL TOTAL ALL PERMITTED PV 2008-2014	2061	205
FINAL TOTAL RES 2008-2014 (Study Period)	**1829***	**190**
FINAL TOTAL NON RES 2008-2014	232*	15

Note: * Includes 12 Installations with no listed permit date

Source: Squyres (2014); Howe Plano PV Permits (July 5, 2015, updated October 19,2015)

3.3.1.3.2.1 Building Permit Data- Installation Dates

An important limitation of the Plano and DFW datasets is the lack of actual system installation dates, which are important for studying trends within the region over time as well as for comparing to trends for the state and the U.S. In addition, it is difficult to investigate the potential impact of the Solarize Plano program on annual installations without accurately identifying installation year.

U.S. and State installation dates primarily reflect interconnection dates provided by utilities, which as mentioned are not available for the DFW region. The final inspection date was determined to be the best available proxy for system installation date, as this usually occurs close in time to the point of interconnection, or the point when the GPV system is officially connected to the utility grid. Unfortunately, it was not clear whether the “date” listed in the original datasets reflected the permit application date, the final inspection date, or another unspecified date. An attempt was made to clarify what the list “date” represented and also to get a sense of the average “processing time,” or time between permit application and final inspection for records where this information was available. Average processing time and a general categorization of “date” for the seven sample cities is summarized in section 3.5.5 of Results.

Plano and six of the eighty-one additional DFW/NCTCOG municipalities use an online building permit and inspection platform that allows for public records searches. Final inspection dates were accessed online for most Plano systems and for the following DFW cities: Colleyville, Denton, Flower Mound, Frisco, Irving, and Keller and compared to dates in the original dataset. Final inspection dates were available for 313/364 (86%) of the records for these seven cities, and were used in place of the original dates listed in the DFW data set. Where final inspection dates were not listed for either DFW or Plano databases, PV installers and city building permit officials were contacted to review the records. When neither installer nor permit official could verify likely installation status and timeframe, installation was confirmed via satellite imagery on Google maps, and the original “date” listed was used for confirmed systems.

According to building permit officials, in the earlier years of PV installations, final building inspections were occasionally not scheduled. In such cases, final inspections were sometimes scheduled when the installer returned to pull a permit for a new PV system. This results in a few records with final inspections occurring more than a year after permit applications were filed, or sometimes not at all (City of Plano Building Inspections staff, personal communications, September 16, 2015).

3.3.1.3.3 Installation Size for for DFW and Plano

The DFW and Plano data sets did not include consistent reporting of system sizes (in W_{DC} or kW_{DC}). In order to estimate annual installed capacity (in $kW_{DC)}$, the number of installations were multiplied by the Texas average (Barbose, & Darghouth (2015b) by average provided, for each year. These estimates are included in the results in section 3.5.1.

3.3.1.3.4 Installed Cost for DFW and Plano

Information on installed costs for residential GPV in the study area was provided by staff at the Lawrence Berkley National Laboratory (LBNL). Staff from the Lawrence Berkley National Laboratory (LBNL) provided a database containing a sample of 5451 records representing residential GPV systems installed in Texas from 2001-2014. Of the sample, 681 sample records were from the DFW NCTCOG region, including 49 from Plano. The average installed costs were aggregated for the 16 county NCTCOG area and also for the City of Plano. LBNL researchers caution that these numbers represent a small sample, and therefore should not be used in statistical analyses. In fact, the sample did not include installations in the study area for 2008 or 2013, and only one installation for 2014. Figures for installed costs are included with those for each scale in section 3.5.1.

3.3.2 Socio-Demographic Variables

Basic socio-demographic information was obtained through the U.S. Census Bureau online (U.S. Census, 2014a, b) for all NCTCOG counties, for DFW/NCTCOG cities with population greater than 5,000, as well as for Texas and the United States. Census data from 2014 were used for population, number of households, and number of housing units. Information was also gathered on variables with possible influence on GPV adoption as indicated in the literature, including median household income and percent bachelor's degree or higher (U.S. Census, 2014b[9]), and percent living in same house as 1 year ago (U.S. Census 2014b[10])

When presented alongside variables for all scales, the DFW county means are used. However, when summary statistics are presented for the study area alone, they represent an aggregation of city level data for the 67 cities reporting GPV systems and with populations greater than 5,000. Cities with population less than 5,000 were excluded because: 1) socio-demographic information was not easily accessible in a consistent format for for cities with populations less than 5,000, and 2) the presence of even small numbers of PV systems in a city with a small population skewed the data. Data summaries are presented for each scale and for the 67 (of 82 reporting) DFW cities with population of 5,000 or greater in section 3.5.3.

[9] 5-year estimates, 2010-2014
[10] 5-year estimates, 2009-2013

In addition, the potential relationship between specific socio-demographic variables and GPV adoption is investigated. Specifically, the DOI literature pointed to an increased likelihood of adoption among those with higher levels of education and income. Also several qualitative studies suggest that a potential barrier to adoption is the concern of a homeowner about how long they will remain in their current home. Pearson's product-moment correlation coefficient is used to determine whether or not there is a positive correlation between the number of installed residential GPV systems among DFW cities, and median household income, percent bachelor's degree or higher, and living in same house as 1 year ago. The null hypothesis (H_0) is that there will be no correlation between the number of installed residential GPV systems among DFW cities, and median household income (MHI), percent bachelor's degree or higher (BD), and living in same house as 1 year ago (SH); the alternative hypotheses is that there is a positive correlation between the number of installed residential GPV systems among DFW cities and median household income ($H_{A\text{-}MHI}$), percent population with bachelor's degree or higher ($H_{A\text{-}BD}$), and percent population living in same house as 1 year ago ($H_{A\text{-}SH}$). Summaries of the sociodemographic variables and results of the correlation, are presented in section 3.5.3.

3.3.3 Utility Data for DFW

As discussed in Chapter 2, a customer's electric utility/ies, both Transmission and Distribution Utilities (TDU) and Electric Service Provider (ESP), have been identified as important to end users in their decision to adopt or not adopt GPV. In particular, utility incentives and net-metering, or electricity buy back plans, are commonly mentioned as important to potential adopters. Therefore, any information on the utilities in the region, contributes to a better understanding of factors influencing adoption.

In Texas, areas served by investor-owned utilities (IOUs) will have transmission and distribution services separated from retail electricity services, while co-op and municipally owned utilities (MOUs) may or may not combine these services. DFW is served by one large investor-owned TDU utility, Oncor, along with several coops and MOUs. Oncor customers have the option of purchasing electricity from several ESPs. The Texas Public Utility Commission maintains a website, www.powertochoose.org, that allows Texas customers to compare current rates available in their area by registered ESPs. In June 2016, there were approximately 50 ESPs listed as offering plans in North Texas (Public Utilities Commission of Texas, 2014).

Information was assembled on the customer base and incentives offered over time for Oncor and the coops and MOUs in the study area (section 3.5.4). Data was not available on ESP customer bases as tied to the study area. The potential impact of ESPs on GPV adoption, and in particular the two that were identified as offering buyback plans during the Solarize Plano project time frame, was studied as a part of the Solarize Plano case study and will be presented in Chapter 4.

In addition to Oncor, coops and MOUs serving the area were identified with the assistance of NCTCOG staff who provided list of eight municipally owned and nine cooperative transmission and distribution utilities with territories in the DFW area (NCTCOG staff, personal communication, September 8, 2015). Staff at each municipal and cooperative transmission and distribution utility and from Oncor, the investor owned utility for the region, were contacted by e-mail and/or telephone, to obtain the the following information, annually, over the study period: number of total and residential customers, number of residential GPV systems, and rebate levels (if any). One of the nine cooperatives listed by the NCTCOG is no longer servicing DFW. Another was missing from NCTCOG's original list, but was mentioned by Rayburn County Electric Cooperative as one of the distribution cooperatives active in their territory.

Along with details on rebate levels over time, Oncor staff explained ERCOT's monthly "Profile Type Counts" database that summarizes the total customers by "profile type," for each utility, and can be further broken down by weather zone. NCTCOG's 16 counties fall within Oncor's 32 county North Central weather zone. The numbers of Oncor's residential and total customers living in the NCTCOG area, were estimated by: 1) estimating the percent of North Central weather zone population that resided in the NCTCOG counties, (93%), and 2) multiplying that figure by the customer classes for the North Central Weather Zone.

The hope was to be able to geographically attribute the data assembled for all DFW area utilities geographically, to investigate potential correlation between utility information and GPV installations. Unfortunately, accurate geographic details for utility service areas and customers were not available at a level that would allow for detailed spatial analysis. Not all data requested was provided. Summarized data are presented in section 3.5.4.

3.3.4 Government Policies and Procedures

As described in Chapter 2, the primary polices identified in the literature as potentially impacting homeowner adoption of GPV relate to net-metering and buy back (Federal and state), regulation of interconnection procedures (state), tax incentives (federal and state), other government issues incentives (state, in locations where incentives such as rebates are issued from government agencies rather than utilities), policy regulating customer incentives provided by utilities (state), HOA (state) and zoning (local) restrictions, and permitting(local).

For the purposes of this study, most information on the impact of these types of government policies and procedures on adoption is limited to the case study in Chapter 4, as provided by interviewees. As described in Chapter 1, a large focus of the NCTCOG Solar Ready II partnership is to work with local governments and other stakeholders to reduce barriers associated with permitting. SRII program organizers have spent the past year and a half working to categorize the status of BMP's among participants and to create specific mechanisms for local governments in the region to improve in this area. The relevance of this initiative will be addressed in the concluding remarks presented in Chapter 5.

3.4 Results

This section presents the results of data collection and analyses described in section 3.3. The best available data on GPV installations and socio-demographic variables are presented for the study area, including the 16 county NCTCOG region and the case study city of Plano, alongside similar metrics for Texas and the U.S. Additionally, pertinent information on regional utilities serving DFW customers is summarized, and average permit processing times are presented for sample DFW cities. Summary data are presented and interesting trends are described, setting the stage for the Solarize Plano case study, identification of regional lessons, and opportunities for future research.

3.4.1 GPV Installation Metrics Across Scales (2008-2014).

Tables 5-8 summarize the basic installation metrics for all scales for which data were available for 2008-2014, including: annual and cumulative number of installed residential GPV systems, average system size (kW_{DC}), residential as a percent of all installations, and pre-incentive installed cost ($\$/kW_{DC}$). As described in section 3.3 information on average system size was not available for the study area, so the annual installed capacity presented in Table 5 for DFW and Plano was estimated by multiplying the number of annual installations by the average residential system size in Texas for each year. The installed cost figures for DFW and Plano represent a very small sample and are included here for reference, with hopes that a more representative sample or census can be obtained in the future. Table 3.6 presents total installations (2008-2014) per housing units for all scales.

Table 5. *Annual Number (#) and Capacity (MW_{DC}) Residential GPV Installations*

	Annual Installations (#)				**Annual Installed Capacity (MW_{DC})**				**Average System Size kW**	
	US	**TX**	**DFW**	**PLANO**	**US**	**TX**	**DFW***	**PLANO***	**US**	**TX**
2008	17,100 [1]	252 [8]	3 [14]	0 [15]	90.45 [1]	0.7 [8]	0.01	0	4.9 [1]	3 [7]
2009	31,280 [2]	513 [8]	64 [14]	6 [15]	156.6 [2]	1.8 [8]	0.29	0.03	5.2 [2]	4.6 [7]
2010	45,500 [3]	895 [8]	174 [14]	25 [15]	262 [3]	4.4 [8]	1.03	0.15	5.7 [3]	5.9 [7]
2011	56,320 [4]	1242 [8]	107 [14]	4 [15]	324 [4]	5.9 [8]	0.60	0.02	5.8 [4]	5.6 [7]
2012	85,500 [5]	1512 [13]	124 [14]	11 [15]	500 [5]	9.3 [8]	0.73	0.06	5.8 [5]	5.9 [7]
2013	145,700 [6]	2110 [13]	429 [14]	44 [15]	900 [6]	14.7 [8]	2.27	0.23	6.2 [6]	5.3 [7]
2014	189,000 [9]	2272 [9]	916 [45]	100 [15]	1231 [10]	15.0 [9]	6.05	0.66	6.5 [10]	6.6**
TOTAL	**570,400**	**87,796**	**1817*****	**190**	**3464.05**	**51.84**	**10.98**	**1.16**		

Note: *Estimated by multiplying installation # by average residential system size in Texas/year. ** Estimated by dividing annual installed capacity by # systems. *** Does not include 12 records with no listed permit date.

Table 6. *Percent (%) Growth in Annual Installations (#) and Capacity (kWh)*

	% Growth in # Annual Installations				% Growth in Annual Installed Capacity			
	US	**TX**	**DFW**	**PLANO**	**US**	**TX**	**DFW**	**PLANO**
2008-2009	83%	104%	2033%	-	73%	173%	3171%	-
2009-2010	45%	74%	172%	317%	67%	141%	249%	434%
2010-2011	24%	39%	-39%	-84%	24%	34%	-42%	-85%
2011-2012	52%	22%	16%	175%	54%	58%	22%	190%
2012-2013	70%	40%	246%	300%	80%	57%	210%	259%
2013-2014	30%	8%	114%	127%	37%	2%	167%	183%
Mean	**51%**	**48%**	**424%**	**167%**	**56%**	**78%**	**629%**	**196%**

Sources: see above; percent change based on annual numbers from table 5.

Table 7. *Residential GPV Installations Number and Capacity as Percent (%) of Total*

	Residential Installations (#) as % of Total				Residential Installed Capacity as % of Total			
	US	**TX**	**DFW**	**PLANO**	**US**	**TX**	**DFW***	**PLANO***
2008	90%	90%	75%	NA	27%	65%	-	-
2009	92%	77%	84%	86%	36%	44%	-	-
2010	91%	83%	83%	93%	29%	17%	-	-
2011	88%	84%	74%	67%	18%	12%	-	-
2012	90%	88%	74%	79%	15%	17%	-	-
2013	94%	90%	90%	90%	20%	17%	-	-
2014	95%	92%	95%	99%	20%	12%	-	-

Note: * Non-residential capacity estimates not available.

Table 8. *Installed Price ($/W DC)*

	US[11]	**TX**[12]	**DFW**[17]*****	**PLANO**[17]*****
2008	$8.84	$7.90	-	-
2009	$8.43	$7.20	$7.67	$6.08
2010	$7.14	$6.20	$7.33	$6.99
2011	$6.31	$5.00	$7.77	$7.63
2012	$5.39	$4.00	$4.90	$4.26
2013	$4.69	$3.50	-	-
2014	$4.27	$3.40	-	-

Note: * Sample size considered too small by the source to be statistically representative

Table 9. *Total Residential Installations (#) per Housing Unit*

	Residential Installations (#) per Housing Unit				Housing Units, 2014[16]			
Cumulative	**US**	**TX**	**DFW**	**PLANO**	**US**	**TX**	**DFW***	**PLANO**
2008-2014	0.00426	0.00084	0.00068	0.00183	133,957,180	10,426,080	2,682,965	103,672

Note: * Housing units are summed for NCTCOG counties, US Census (2014a)

References for Tables 5-9. Note: p.c. below indicates personal communication

1 Sherwood (2009).
2 Sherwood (2010).
3 Sherwood (2011)
4 Sherwood (2012)
5 Sherwood (2013)
6 Sherwood (2014)
7 Sherwood, L. (p.c., June 29 2015)
8 Sherwood, L. (p.c., August 12 2015)
9 SEIA staff (p.c., September 25 2015)
10 GTM Research/SEIA (2014)
11 Barbose, &. Darghouth (2015a)
12 Barbose, & Darghouth (2015b)
13 Average metric from 8 & 9
14 Squyres (2014)
15 Howe (2015)
16 US Census (2014a)
17 Barbose (2016)

Some interesting trends can be noted from the summary data. Growth in residential scale GPV installations has been steady from 2008-2014 in the U.S (1008% growth) and in Texas (802% growth), with growth in Texas lagging slightly behind the U.S. As can be seen in figures 3-6, the growth in residential GPV installations follows the same pattern for Plano as for the DFW region, but is different than the growth trends for the state or the U.S. Very few residential systems (10) had been installed in the region prior to 2008, and none are on record in Plano until 2009.

Figure 3. Annual U.S. Residential GPV Installations

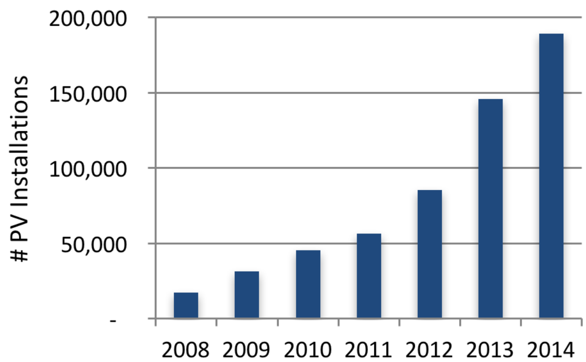


Figure 4. Annual Texas Residential GPV Installations

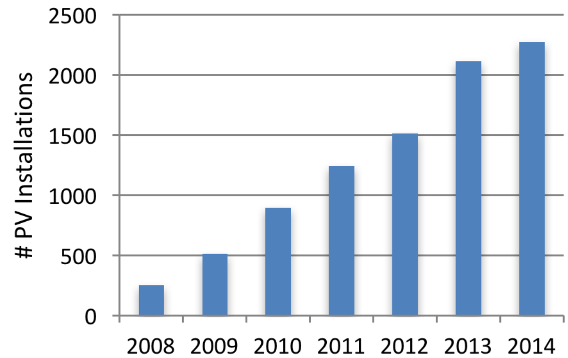


Figure 5. Annual DFW GPV Installations

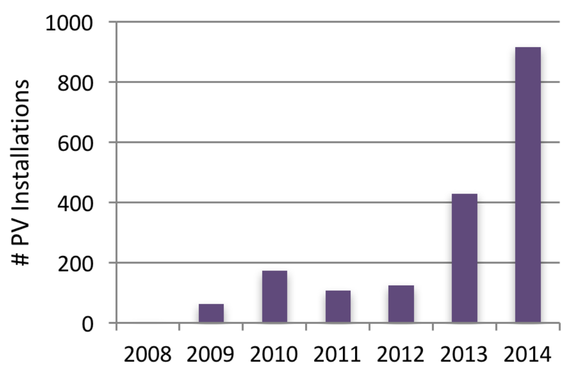
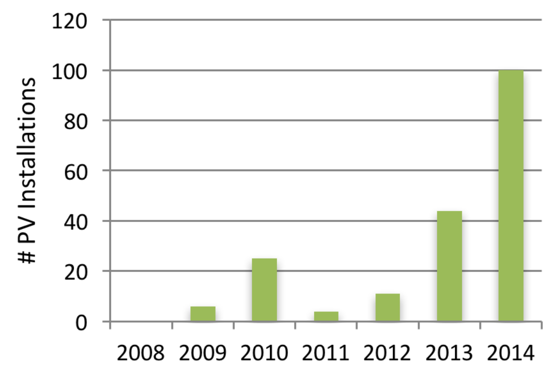


Figure 6. Annual Plano GPV Installations

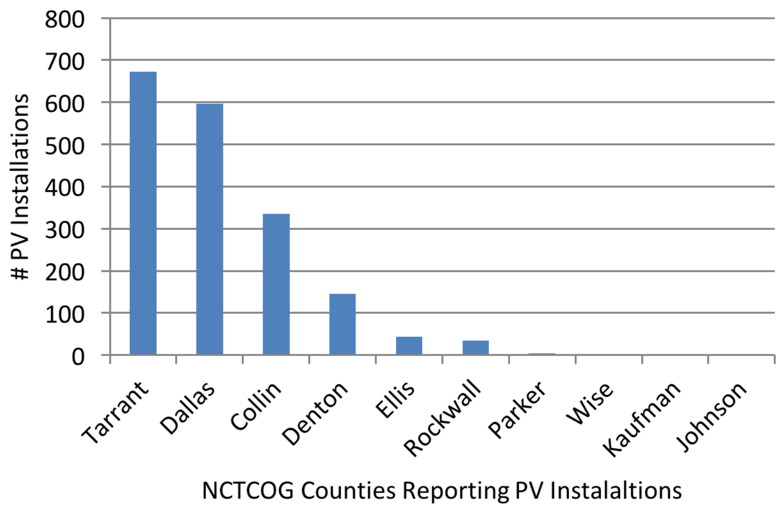


3.4.2 DFW GPV Distribution

For both DFW and Plano, installations grew from 2008-2010, dipped noticeably in 2011 and 2012, and then continued to grow at a tremendous rate from 2012-2013 (DFW= 246%and Plano= 300%) and 2013-2014 (DFW= 114% and Plano= 127%). Overall from 2008-2014 regional growth in residential GPV installations was 30 times that for the U.S. and approximately 38 times the growth rate for Texas; Plano installations grew at a rate 1.5 times that for the U.S. and about 2 times the rate for Texas. While the region has a higher overall growth from 2008-

2014 than Plano, Plano installations have growth at a higher annual rate than the region since 2011.Figures 3-8 present total and relative installations in DFW at the county and city levels. Data represent the NCTCOG cities (67/169) and the associated counties (10/16) with systems included in the Squyres dataset. The 10 GPV systems installed prior to 2008, are included in totals.

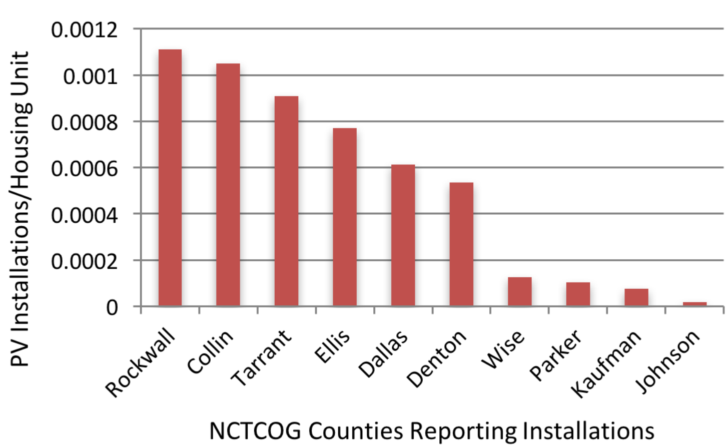
Figure 7. DFW County Total GPV Installations, 2004-2014



	County	Count	Percentage
1	Tarrant	672	36.54%
2	Dallas	596	32.41%
3	Collin	335	18.22%
4	Denton	146	7.94%
5	Ellis	44	2.39%
6	Rockwall	34	1.85%
7	Parker	5	0.27%
8	Wise	3	0.16%
9	Kaufman	3	0.16%
10	Johnson	1	0.05%
	Total	**1839***	
Mean for all Counties		**114.9**	

Note: * Includes 10- pre 2008 systems

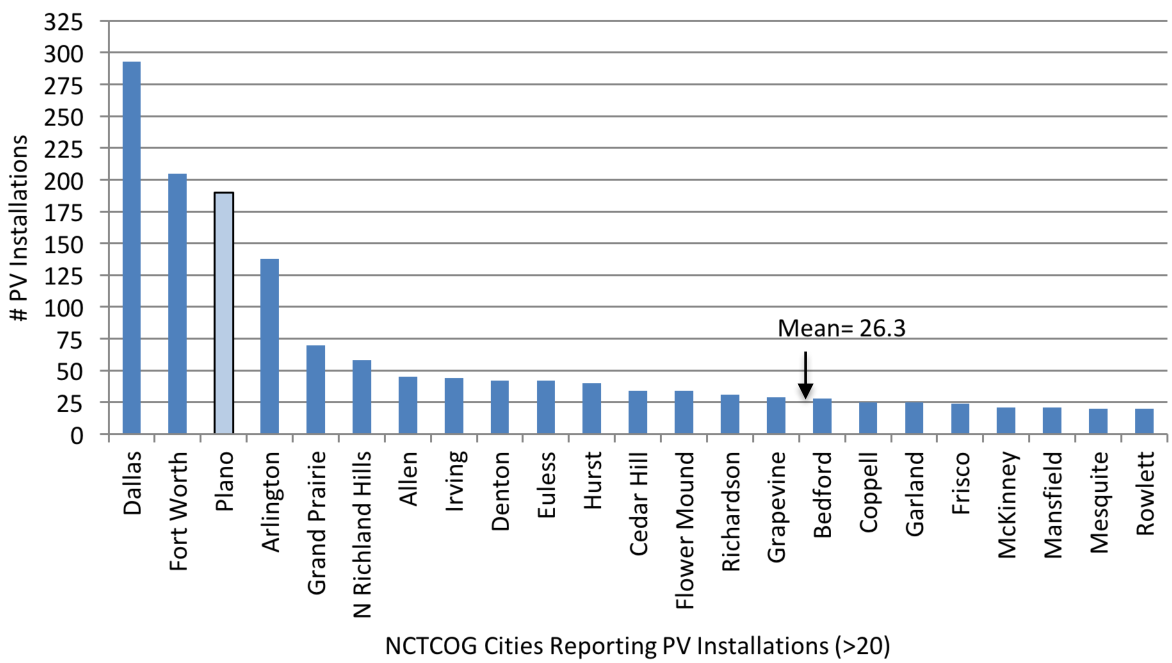
Figure 8. DFW County GPV Installations/Housing Unit, 2004-2014



	County	# per housing units
1	Rockwall	0.001110168
2	Collin	0.001022692
3	Tarrant	0.000908932
4	Ellis	0.000771375
5	Dallas	0.000611623
6	Denton	0.000520668
7	Wise	0.000125282
8	Parker	0.000104587
9	Kaufman	0.000076546
10	Johnson	0.000016939
	Mean	0.000526881

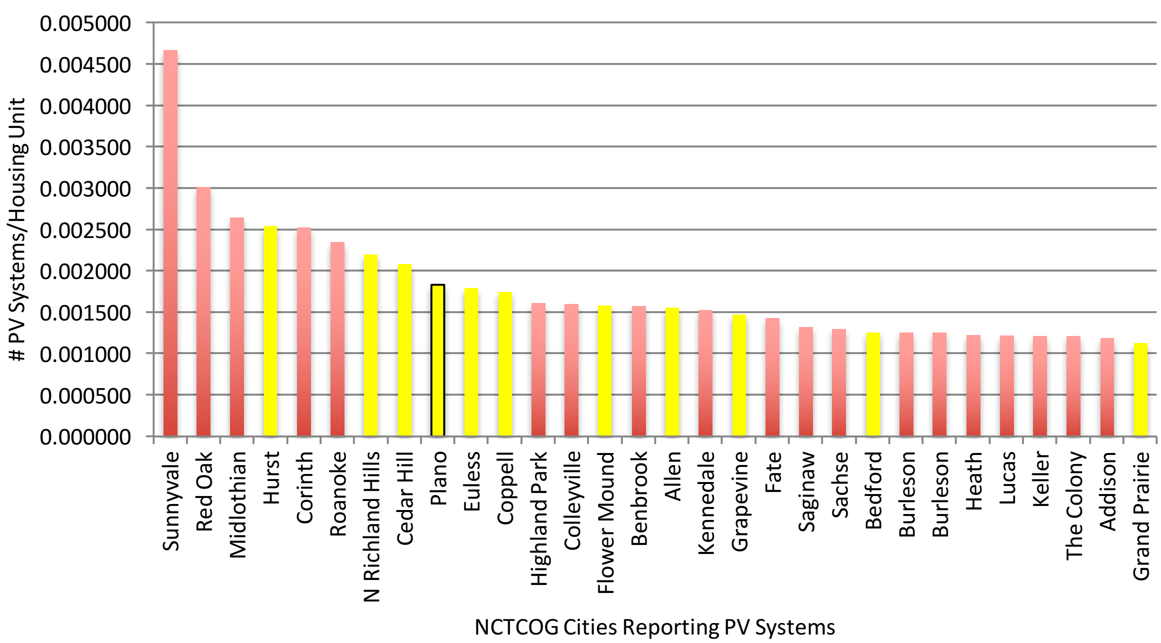
While Figure 7 presents absolute numbers of GPV installations per county, it is also useful to look at relative installations metrics to adjust for scale. Figure 8 presents cumulative installation per household (#/household) for each county. As can be seen in Figures 7 and 8, Collin, Tarrant, and Dallas counties remain relatively high adoption counties using both total and relative installation metrics; Parker, Wise, Kaufman and Johnson remain relatively low adoption counties using both metrics, and Denton remains above the mean for both total and relative installations. Erath, Hood, Hunt, Palo Pinto, Somervell, and Navarro counties report no installations through 2014. It is interesting to note that Rockwall and Ellis counties have very high levels of adoption per household but low total installations.

Figure 9. DFW Cities with > 20 Residential GPV Installations, 2004-2014



Total and relative installations for all reporting NCTOCOG cities are included in Appendix A. Figure 9 illustrates the total GPV installations for DFW cities (23/67) with twenty or more residential GPV systems installed through 2014 (mean =26.3 total installations). Figure 10 presents NCTCOG cities (30/67) with populations of 5,000 or greater and with an average number of installations per households greater than the mean (.001109)[11]. Of the twenty-three DFW Cities with twenty or more total residential GPV systems[12], eleven also have relative installations numbers greater than the mean. These cities (highlighted in yellow in Figure 10), are referred to in this study as "high performing" cites, and stand out as worthy of further study. than the regional mean[13].

Figure 10. DFW County Residential GPV Systems Installed (2004-2014)/Housing Unit



[11] For cities with populations greater than 5,000
[12] And population greater than 5,000
[13] For cities with populations greater than 5,000.

Plano, the case study city, has the 3rd highest total residential installation numbers and is 5th in the region for installations per household. Of the "high performing" GPV cities, Plano has by far the largest number of installations, and represents 11% of the region's installations for the study period. Additionally, Plano's number of installations per housing unit is 65% higher

3.4.3. Socio-demographic Measures

Basic socio-demographic information is presented for all NCTCOG counties, for DFW/NCTCOG cities with population greater than 5,000, as well as for Texas and the United States, including population, households, housing units, median household income, percent of population with a Bachelor's degree or higher, and percent of population living in the same house and one year ago. This information contributes to a study of GPV adoption by providing some background information on the communities and households where adoption decisions may be taking place. Where possible, relationships and trends between adoption measures and socio-demographic measures are investigated. Table 10 presents installation metrics alongside socio-demographic measures of interest, for all scales of interest. Tables 11 and 12 then focus on the study area, and include cities from the NCTCOG dataset.

Table 10. *GPV metrics and Socio-Demographic Variables for the U.S., Texas, DFW Counties, and Plano*

	#	**# Per Housing Units**	**Population[1]**	**Households[1]**	**Housing Units[1]**	**Median Household income[2]**	**Bachelors Degree or Higher[2]**	**Living in Same House as 1 yr ago[3]**
U.S.	**570,400**	0.004258	318,857,056	116,211,092	133,957,180	$53,046.00	29%	85%
Texas	**8,796**	0.000844	26,956,958	9,013,582	10,426,080	$51,900.00	27%	83%
DFW *	**1839*****	0.000685	7,040,424*	2,375,872*	2,682,965*	$58,031.44**	25%**	84%**
Plano	**190**	**0.001832**	278,480	100,136	103,672	$82,484.00	54%	87%

Note: County level data summed* or averaged ** for all NCTCOG counties; *** 2004-2014 Permit data
Source: U.S. Census (2014a[1]), and (2014b, 5-year averages, 2010-2014[2] or 2009-2013[3])

Table 11. *Summary Descriptive Statistics for DFW Cities (67/82 reporting) with Population ≥ 5,000*

	#	% of DFW Installs	# Per Housing Units	Population[1]	House-holds[1]	Housing Units[1]	Median Household income[2]	Bachelors Degree or Higher[2]	Living in Same House as 1 yr ago[3]
Mean	**26.9**	**1%**	**0.001109**	**88,051.21**	**30236.2**	**32,099.3**	**$77,837.30**	**36%**	**84%**
St. Error	6.09	0%	0.000099	22,997.77	8166.18	8,966.30	$4,131.66	2%	1%
Median	12.0	1%	0.001054	38,453.00	12840	13,591	$69,088	32%	85%
St. Deviation	49.8	3%	0.000812	188,244.87	66843.1	73,392.3	$33,819.11	17%	6%
Minimum	1	0%	0.000075	5,766	1,792	1,641	$39,747.00	10%	61%
Maximum	293	16%	0.004670	1,281,047	467,501	516,639	$192,946	83%	97%
Range	292	16%	0.004595	1,275,281	465,709	514,998	$153,199	0.731	0.365

Note: City level data for the 67 cities; 2004-2014 Permit data
Source: U.S. Census (2014a[1]), and (2014b, 5-year averages, 2010-2014[2] or 2009-2013[3])

Table 12. *GPV Metrics and Socio-Demographic Variables for DFW Cities with > 20 Residential GPV Installations (2004-2014) and with Population ≥ 5,000.*

	City	#	% of DFW Installs	# Per Housing Units	Population	House-holds	Housing Units	Median Household income	Bachelors Degree or Higher	Living in Same House as 1 yr. ago
1	Dallas	293	16%	0.00057	1,281,047	467,501	516,639	$43,359	30%	81%
2	Fort Worth	205	11%	0.00070	812,238	268,884	291,086	$52,492	27%	82%
3	**Plano**	**190**	**10%**	**0.00183**	**278,480**	**102,182**	**103,672**	**$82,944**	**55%**	**87%**
4	Arlington	138	8%	0.00095	383,204	133,601	144,805	$53,055	29%	80%
5	Grand Prairie	70	4%	0.00112	185,453	58,531	62,424	$55,336	23%	86%
6	N Richland Hills	58	3%	0.00220	68,529	24,853	26,395	$62,927	31%	84%
7	Allen	45	2%	0.00156	94,179	29,344	28,877	$102,120	53%	87%
8	Irving	44	2%	0.00048	232,406	82,817	91,128	$50,942	34%	77%
9	Denton	42	2%	0.00091	128,205	42,961	46,211	$48,518	38%	69%
10	Euless	42	2%	0.00179	53,630	21,315	23,447	$54,619	32%	79%
11	Hurst	40	2%	0.00254	38,733	14,578	15,761	$53,488	26%	84%
12	Cedar Hill	34	2%	0.00208	48,084	15,833	16,338	$67,913	30%	89%
13	Flower Mound	34	2%	0.00158	69,650	21,952	21,570	$121,549	58%	89%
14	Richardson	31	2%	0.00076	108,617	39,576	40,630	$70,959	51%	82%
15	Grapevine	29	2%	0.00147	50,844	19,349	19,685	$75,931	46%	81%
16	Bedford	28	2%	0.00126	48,908	21,136	22,301	$60,373	35%	83%
17	Coppell	25	1%	0.00174	40,678	14,309	14,343	$111,325	63%	86%
18	Garland	25	1%	0.00031	235,501	74,989	80,834	$51,997	22%	85%
19	Frisco	24	1%	0.00057	145,035	43,491	42,306	$112,155	58%	85%
20	McKinney	21	1%	0.00044	156,767	47,490	47,915	$82,988	45%	84%
21	Mansfield	21	1%	0.00110	62,246	19,744	19,106	$89,774	41%	89%
22	Mesquite	20	1%	0.00038	144,416	47,927	51,952	$49,837	18%	83%
23	Rowlett	20	1%	0.00105	58,407	18,251	18,969	$83,442	31%	92%

Note: Highlighted Cities have total # of Residential GPV Installations > 20 (mean is 26.9) and # per Housing Units > Mean (0.001109).
Source: U.S. Census (2014a and 2014b)

Table 11 presents summary descriptive statistics for the 67 cities with populations of or greater than 5,000, and Table 12 presents measures for each city (23) reporting 20 or more residential GPV installations through 2014. The eleven high performing cities (those with greater than 20 residential GPV installations and number per housing units greater than the mean (0.001109)) are highlighted. Installation and socio-demographic measures presented for each of the 67 cities (with populations of or greater than 5,000) in Appendix A.

3.4.3.1 Socio-demographic Trends

Several interesting trends are apparent in this data and are described here, along with the results of the Pearson's product-moment correlation coefficient between number of GPV installations among DFW cities and select socio-demographic variables. Table 13 extracts information for the eleven high performing cities in Table 12, and includes for comparison purposes means for several variables for those 11 cites, the sample of 67 cities with populations of or greater than 5,000, and the DFW at large (U.S. Census, 2014a, b).

It is important to note that those cities reporting installations and with a population of ≥ 5,000, do appear to have higher average median household incomes (approximately 34% higher) and levels of education (approximately 11% more of the populations in these cities have bachelor's degree or higher) compared to the DFW region, but no notable difference is seen between DFW cities with GPV installations and the DFW mean for living in the same house as 1 year ago. Results of the Pierson's product-moment correlation coefficient used to test these specific relationships will be described before summarizing trends noticed among High performing cities.

Table 13. *High Performance Cities*[14] *GPV Metrics and Socio-Demographic Variables*

	City	#	% of DFW Installs	# Per Housing Units	Population	House-holds	Housing Units	Median Household income	Bachelors Degree or Higher	Living in Same House as 1 yr ago
1	**Plano**	**190**	**10%**	**0.00183**	**278,480**	**102,182**	**103,672**	**$82,944**	**55%**	**87%**
2	Grand Prairie	70	4%	0.00112	185,453	58,531	62,424	$55,336	23%	86%
3	N Richland Hills	58	3%	0.00220	68,529	24,853	26,395	$62,927	31%	84%
4	Allen	45	2%	0.00156	94,179	29,344	28,877	$102,120	53%	87%
5	Euless	42	2%	0.00179	53,630	21,315	23,447	$54,619	32%	79%
6	Hurst	40	2%	0.00254	38,733	14,578	15,761	$53,488	26%	84%
7	Cedar Hill	34	2%	0.00208	48,084	15,833	16,338	$67,913	30%	89%
8	Flower Mound	34	2%	0.00158	69,650	21,952	21,570	$121,549	58%	89%
9	Grapevine	29	2%	0.00147	50,844	19,349	19,685	$75,931	46%	81%
10	Bedford	28	2%	0.00126	48,908	21,136	22,301	$60,373	35%	83%
17	Coppell	25	1%	0.00174	40,678	14,309	14,343	$111,325	63%	86%
H.P. Sample Mean		54.1	-	0.00174	88,833	31,217	32,256	$77,138.64	41%	85%
67 City Mean		26.9	-	0.00111	88,051	30,326	32,099	$77,837.30	36%	84%
All DFW Mean		-	-	-	-	-	-	$58,031.44	25%	84%

3.4.3.1.1 Correlation Analysis

Pearson's correlation coefficient is used to determine if there is a positive correlation between the number of installed residential GPV systems among DFW cities, and median household income, percent bachelor's degree or higher, and living in same house as 1 year ago. The null hypothesis (H_0) is that there will be no correlation between the number of installed residential GPV systems among DFW cities, and median household income (MHI), percent bachelor's degree or higher (BD), and living in same house as 1 year ago (SH); the alternative hypotheses are that there are positive correlations between the number of installed residential

[14] High performing cities have total # of Residential GPV Installations > 20 (mean is 26.9) and # per Housing Units > Mean (0.001109).

GPV systems among DFW cities and median household income ($H_{A\text{-}MHI}$), percent population with bachelor's degree or higher ($H_{A\text{-}BD}$), and percent population living in same house as 1 year ago ($H_{A\text{-}SH}$). With degrees of freedom = 65 (67 DFW cities with populations of or greater than 5,000 minus 2), using one-tailed test for significance, the critical value (c.v.) at p = 0.05 is 0.2027 (one tailed), and the critical value for p=.01 is 0.2837. The values (see below) for r_{MHU}, r_{BD}, and r_{SH} exceed the critical value at p=.05; none exceed the c.v. at p=.01.

r_{MHI} (65)= 0.208644768, $p < 0.05$ (one tailed)
r_{BD} (65)= 0.211945638, $p < 0.05$ (one tailed)
r_{SH} (65)= 0.205750754, $p < 0.05$ (one tailed)

Therefore, the null hypothesis can be rejected for variables MHI, BD, and SH, at the level of significance of p< 0.05. The alternative hypotheses that there is a positive correlation between the number of installed residential GPV systems per housing unit among DFW cities, and median household income ($H_{A\text{-}MHI}$), percent population with bachelor's degree or higher ($H_{A\text{-}BD}$), and percent population living in same house as 1 year ago ($H_{A\text{-}SH}$) is accepted at p< 0.05. Although these correlations are statistically weak, they indicate that the dependent variables influence the independent variable of number of installed systems in a non-random way, which mirrors conclusions based on the summary data presented above and for high-performing cities (following section).

3.4.3.1.2 High Performing Cities

The eleven cities identified as "high performing cites" in terms of residential GPV adoption, are similar to the larger sample of 67 cities in median household income and also for living in the same house as 1 year ago. However, the high performing cities have approximately

14% higher average levels of education than the sample mean of 67 cities and approximately 64% higher than the DFW mean. Plano has the highest total number of installations for the high performing cities, and the fourth highest relative adoption levels. Flower Mound, Coppell, Allen, and Plano have the highest median household income and levels of education of these cities. These findings will lead to recommendations for further research and opportunities in the region based on the case study of Solarize Plano.

3.4.4 DFW Transmission and Distribution Utilities

Table 14 summarizes information on the customer base and incentives offered over time for Oncor and the coops and MOUs in DFW, including: number of residential and non-residential customers, number of residential GPV systems in service territory, and PV rebate levels (\$/installed W_{DC}). Not all data were tracked or publically available for each utility, and three of the utilities did not provide data. The hope was to be able to attribute this data geographically, to correlate utility information with GPV installations. Unfortunately, accurate geographic details for utility service areas and customers were not available at a level that would allow for such analysis.

This information does, however, contribute to a more complete picture of the utilities and the potential influence, especially of incentive levels, on GPV adoption in the region. For example, one can see that Oncor has had a very steady rebate for GPV over the entire study period, and that this rebate is available to the largest proportion of DFW residents (approximately 78% of residential customers represented in Table 14) when compared to other utilizes. Unfortunately, approximately 10% of residential customers represented in utility analysis, do not qualify for rebates, and rebate levels and qualifications are highly variable among the remaining utilities.

Another seven percent of customers represented in Table 14 are in CoServ territory which is further investigated in Chapter 4. One can also see that Denton Municipal Electric has provided the highest rebate level in the area since 2009. It is somewhat surprising, therefore that Denton, while having absolute and relative installation measures above the mean, does not have more installations per household. This information provides an important background for the Solarize Plano case study in Chapter 4, identifies limitations in existing data, and also points to opportunities for future research.

Table 14. *DFW Transmission and Distribution Utilities.*

UTILITY		# Total Customers	# Res. Customers	# Res. PV systems	Rebate levels over time $\$/W_{DC}$							
					<2008	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
IOU	Oncor	*2,397,734*[1]	*2,077,772*[1]	670	No data	$2.60	$2.46	$2.46	$2.46	$2.00	$1.28	$1.09
MUNI	Garland Power and Light	69,000	65,000	50	0	0	0	0	0	0	0	$1.50
	Denton Municipal Electric	50,678	44,759	60	0	0	$3.00	$3.00	$3.00	$3.00	$3.00	$1.50
	Weatherford Electric	14,355	12,103	2	0	0	0	0	0	0	0	0
	Acton Municipal Electric	3,631	2,680	0	0	0	0	0	0	0	0	0
	Sanger Electric Utilities	2,528	2,067	1	0	0	0	0	0	0	0	0
	Farmersville Electric	*1,419*	*1,173*	0	0	0	0	0	0	0	0	0
	Greenville	*14,000*	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
	Bridgeport	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
TRANS. & DIST. COOP	Trinity Valley Electric Coop	69,000	*40,000*	146	0	0	0	0	0	0	0	0
	United Electric Coop	80,000	68,000	89	0	0	0	$1,000*	$1,000*	$1,000*	$1,000*	$1,000*
	CoServ	150,338	136,808	87	0	0	0	$5,000	$5,000	$5,000	$5,000**	$1,000
	Tri-County Electric Coop	100,933	87,078	50	0	0	0	0	0	0	0	0
	Farmers Electric	41,629	40,172	46	0	0	0	0	0	0	$2.00	$2.00
	Greyson -Collin Electric Coop	44,000	41,800	*not tracked (<40)*	0	0	0	0	0	0	0	0
	Navarro County Electric Coop	15,700	14,300	19	0	0	0	0	0	0	0	0
	Wise Electric Coop	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
TRANS. ONLY COOP	Rayburn County Electric Coop	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: Italicized numbers are estimates
*(> or = 1 kW) ** rebate reduced at the end of 2013
Sources: Data provided by utility from each utility, February 2016)
[1] ERCOT 2015

3.4.5 Permit Processing Time

Table 15 summarizes the processing time, or the average number of days from permit application to final inspection, for the 7 cities with online access to permit records. These data were originally collected in an attempt to better estimate installation dates for the DFW and Plano datasets, but provide too small of a sample from which to generalize. As indicated in the "Date" column in Table 15 for the 7 sample cities, the date listed in the original DFW dataset referenced the permit application date for most of the sample cities, which occurred on average more than two months prior to the final inspection dates.

This small sample does provide useful information for the NCTCOG SR II initiative. The SRII effort has been specifically targeting permitting as a barrier to GPV, with the aim of streamlining the process and making it more consistent across DFW municipalities. The average processing time for 2008-2014 for the sample was 61.5 days, and 73.6 days for 2014. It was interesting to note that Plano's processing time was greater than the mean for the overall study time frame, and less than the mean for 2014. For 2014, Flower Mound and Denton had the longest processing time. A public records request for both application and final inspection dates for a broader sample of permitted GPV systems, would allow for a more complete regional study of permit processing time.

Table 15. *GPV Processing Time (Average # of Days from Permit Application to Final Inspection)*

City	Days (2014)	Average Days (2008-2014)	"Date"*
Colleyville	62.5	57.5	A
Denton	94.6	72.1	F
Flower Mound	103.6	61.0	A
Frisco	62.0	48.6	B
Irving	62.0	70.7	B
Keller	60.8	44.9	A
Plano	70.0	76.0	A
AVERAGE	73.6	61.5	

Note: * Date listed in original database discovered to be "A"- permit application date, "F"-final inspection date, or "B" a date in between.

3.5 Discussion

In this chapter, a variety of baseline measures on residential GPV installations and socio-demographic variables have been presented for all scales of interest, and in more detail for the study area of DFW and the city of Plano. The data present a very clear picture of the number of number and location of installations in the region, and good estimates for installed regional capacity. Installation trends for the region and for Plano are compared to Texas and the U.S., showing substantial recent growth in annual installations as compared to Texas and the U.S. Additionally, sociodemographic analyses indicate that the areas with GPV adoption have relatively high levels of education, median family income, and percent living in the same house as one year ago, compared to the DFW region as a whole.

Several cities were identified, with high absolute and relative indicators for adoption These "high performing" cities appear to have populations with substantially higher levels of education and median family income than is the mean for DFW in general, as well as higher levels of education than other DFW areas reporting GPV installations. Plano has both high absolute and relative levels of adoption, and is one of four high performing cities with the highest levels of education and median household income for the region, indicating that perhaps lessons from Chapter 4 may be especially pertinent to the other 3 high performing cities: Flower Mound, Coppell, and Allen.

Also highlighted in this chapter is the fact that most residential homeowners in the DFW area are served by Oncor for transmission and distribution, and have therefore been consistently eligible for stable and rather substantial GPV rebates; approximately ten percent of residential customers are not eligible for rebates, and rebate levels are highly variable among the remaining utilities serving the area. It is interesting to note that the city offering the highest rebate levels is not one of the high performing cities in terms of adoption. While no real data were available for Electric Serve Provider customer bases, especially tied to geography, more information will be learned about this area in the case study analysis.

Squyres and Howe provided an important contribution to regional tracking and understanding of baseline installation metrics, with their permit based datasets. Annual public reporting of installation metrics by Texas utilities, including pre-incentive installed cost, size, and location (at least by zip), would provide a more thorough baseline and mechanism for trend analyses, and allow for more robust statistical evaluation of the relationship between the variables of interest described here, and others that may emerge though qualitative investigation.

Many of the installation metrics and regional trends presented in this chapter have not been previously compiled and the presentation here aims to provide a baseline for regional study over time, as well as a reference point for analyzing the connection between concepts identified in the qualitative analysis and quantitative installation trends. Chapter 4 provides an in depth study of factors influencing adoption in the Plano area among Solarize Plano program participants, with the goal of evaluating the program's effectiveness and identifying lessons that might be transferrable to the region in general.

CHAPTER 4

THE SOLARIZE PLANO PROGRAM

4.1 Overview

In this chapter, the story of the Solarize Plano pilot project is told from the perspective of the organizers, homeowners, city staff, and installers who participated. As discussed in Chapter 2, the Diffusion of Innovations and social marketing research consistently finds that programs or strategies promoting adoption of a technology or energy saving behavior, without proper consideration of the local context and the factors important to potential adopters, fail to be effective. The importance of adopter-centric research in explaining and addressing geographic and socio-economic nuances in adoption has become clear. In-depth interview and analysis methods provide excellent tools for investigating the perceptions, values, and experiences, of those people making the adoption decision. Concepts from the literature can be considered within the local context, and also new, previously unexplored, concepts may emerge from interviewees. In this way, interview based qualitative methods can contribute to evaluation and development of regionally suited policies and programs.

In this chapter, in-depth interviews are used to identify concepts, including personal attributes, which influence PV system adoption among participants and to evaluate the effectiveness of the project and the model for increasing residential GPV adoption. Socio-demographic measures are compared between adopters and non-adopters within the Solarize Plano program, and between program participants and averages for Plano, the region, Texas, and the U.S. (Section 4.4.3). Data on participant PV system electricity production and energy costs are analyzed to see how actual PV system performance and economic savings compare to participant expectations. Finally, the impact of Solarize Plano on the City of Plano's installation metrics is also assessed (Section 4.6). Methods and findings will be reported in each subsection below.

4.2 The Solarize Model

The Solarize model was originally developed in the Mount Tabor neighborhood of Southeast Portland, Oregon in 2009 as a means to make purchasing and installing PV "easier and more affordable (Rubado, 2010)," particularly through the use of a group purchase model (see below). As figure 11 illustrates, the typical process for an individual homeowner to adopt a GPV systems involves many steps, some of which are confusing and time consuming.

The Solarize model ushers many people through the process together in an accelerated timeframe. The group purchase model involves securing commitments from several homeowners to use an installer selected early in the process, by a sub-committee or founding group. Individual PV systems are installed at a set cost, within an established timeframe. The idea is that the group purchase model will reduce effort on the part of the homeowners and reduce costs for the installer who can pass along savings to the customers in the form of lower installation prices. Due to the "unprecedented success" (Rubado, 2010) of the model, it has been subsequently adopted and/or modified by several other communities. Where implemented, the Solarize model has achieved reduced installation prices in $/installed watt and increased installation numbers and rates (Irvine, Sawyer, and Grove, 2011, p. 4; MCEC, n.d. Solarize Connecticut, 2015; USDOE, n.d.). The National Renewable Energy Laboratory (NREL) has also developed a how-to manual, "The Solarize Guidebook" authored by Irvine, Sawyer, and

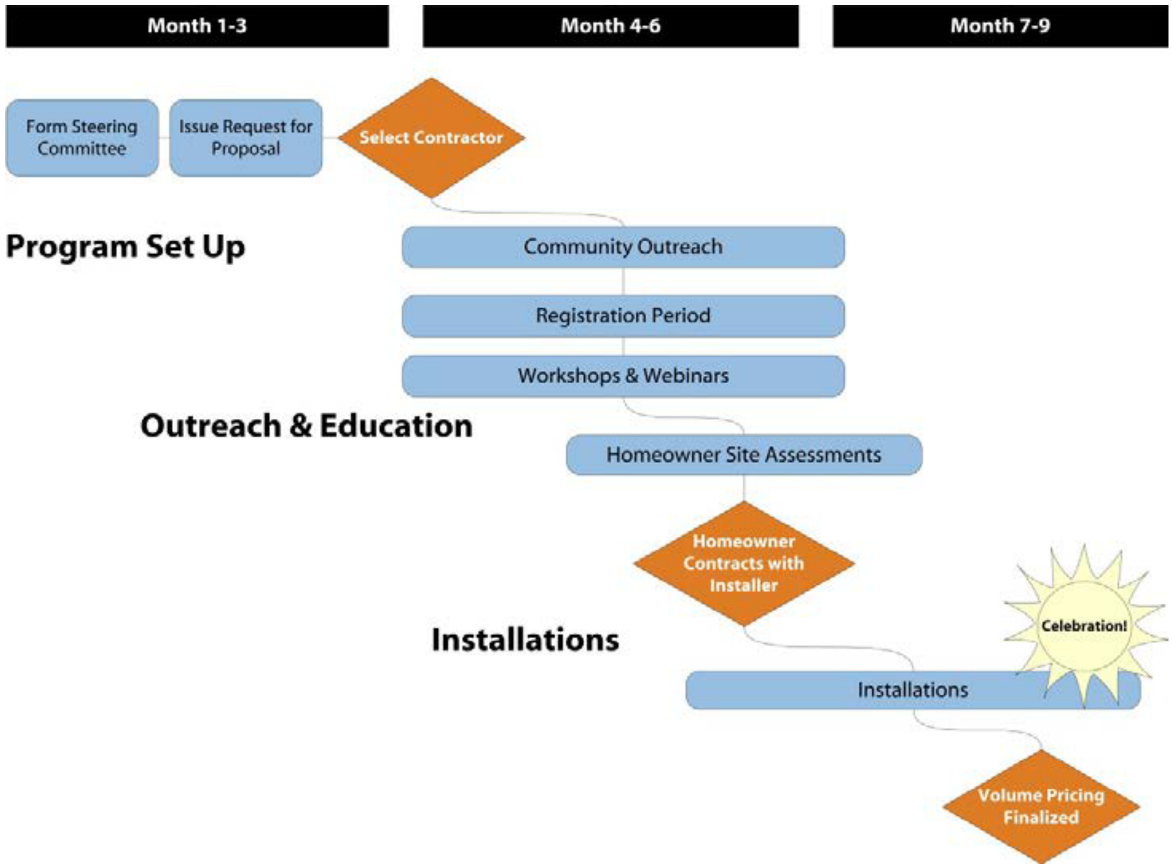
Grove(2011), to walk communities through the process of developing a Solarize program.

Figure 12 outlines the basic steps involved in a typical Solarize project.

Figure 11. Typical Process for Individual Purchase /installation of GPV

- Interest in PV
- Research
- Site
- Find Installer
- Estimate
- Budget/Plan
- Permitting/Incentives (rebate)
- Preliminary Inspections
- Installation
- Final Inspections
- Buyback Rate
- Incentives (tax)
- Maintenance

Figure 12. Sample Solarize Project Timeline. (Irvine, Sawyer, and Grove, 2012, later updated p. 21)



Source: Irvine, Sawyer, and Grove (2011, later updated, p. 21)

On May 20, 2013, a representative from The Solar Foundation, a Washington D.C.-based non-profit dedicated to facilitating solar energy adoption, presented the "Solarize" model to staff from several north Texas local governments and interested members of the public at a North Central Texas Council of Governments (NCTCOG) "Solar Powering Your Community" meeting. The three future Solarize Plano project organizers were in attendance, and left inspired to bring the model to Plano. Enrollment in the pilot Solarize Plano program began within weeks of this NTREG meeting. Details on the Solarize Plano pilot project are presented following discussion of the interview methodology.

4.3 Interview Methods

The sampling frame of 201 Solarize Plano program enrollees was provided by Solarize Plano organizers, and included homeowners who enrolled in the program online between June and October 2013. One non-adopting homeowner from round two of the program was accidentally included in the sampling frame provided by project organizers. This was not discovered until the interview was in process. Upon analysis of the interview, this deviation was determined to not be of great significance to his responses, and his interview was included.

Solarize Plano organizers sent emails inviting participation in the study to the following groups: those who installed systems as a part of the pilot program (N = 20), those who received site surveys as a part of the program but did not install systems (N = 30[15]), and those who did not receive a site survey, which was a prerequisite to installing a system (N = 151). E-mails included a description of the study and the researcher's contact information. Thirteen adopters responded to the researcher and agreed to be interviewed. Interviews were scheduled with ten of these respondents as determined primarily by participant availability. Ten non-adopters responded to the researcher and agreed to be interviewed, including 6 who had received a site visit as a part of the process and 3 who had not; all were interviewed. The sample was purposive and self-selected.

A total of 26 in-depth interviews were conducted from August through November of 2014, with Solarize Plano project participants, including 22 homeowners, 3 project organizers, 1 city staff member, and 2 representatives from the selected installation company. Of these, nineteen interviews were conducted with homeowners from the pilot Solarize Plano program

[15] Includes one known "non-adopter" participant from round 2.

(2013-2014) and one interview was with a participant from the second program round (2014), three interviews were with project organizers, one was with the City of Plano staff involved with the program, and two were with representatives from the selected installation company for the project.

Ten of the homeowner interviews were with “adopters” (10/20 program enrollees who installed PV as a part of the program), including one couple where both participated in the interview; ten interviews were with “non-adopters” (10/181 program enrollees who did not install), including one couple where both participated in the interview. In two of the homeowner interviews, one adopter and one non-adopter, spouses were present for part of the interview but did not actively participate.

Participants were given the choice to meet at their home or a public location for the interviews, which lasted from 24- 93 minutes (mean of 46.4 minutes). One participant was interviewed by phone, as he had moved out of area. An interview guide was used, consisting of 10 (non adopters) to 12 (adopters) open-ended, semi-structured questions (Appendix B). Interviewees also completed a socio-demographic questionnaire (Appendix C).

The three Solarize Plano organizers, one of whom added to his existing PV system through the pilot program, and two representatives from the program’s selected installation company, were interviewed for their unique experience and perspective on the Solarize Plano program and GPV adoption in the region. Additionally, one City of Plano staff member was interviewed to study staff perspectives and experiences with local GPV adoption and the Solarize Plano program. These interviews were guided by a series of 12 to 14 semi-structured questions (Appendix B) and lasted from 26 to 103 minutes (mean of 46.9 minutes).

Interviewees had the choice of meeting at their home, work, or a public location, or by telephone.

Approval from the University of North Texas Institutional Review Board (IRB) was obtained, and appropriate consent information was reviewed with signatures obtained from participants prior to conducting interviews. Interviews were recorded, transcribed, and analyzed with qualitative techniques consistent with Corbin and Strauss (2008) and Rubin and Rubin (2005). Confidentiality of those interviewed is maintained through the use of pseudonyms.

Corbin and Strauss (2008) and Rubin and Rubin (2005) advocate the use of inductive methods that allow concepts to emerge from participants. Interview questions are open-ended and serve as guides. The researcher listens for concepts, probes for additional detail, and follows up on emerging concepts as additional interviews are conducted. Interviews are coded, or systematically reviewed for repeating concepts and themes. These patterns and themes can be comparatively explored within project interviews and with the literature. For the Solarize Plano case study, these methods allow for a deep understanding of factors relevant to GPV adoption in Plano, the influence of the Solarize Plano program, and the potential relevance of the Solarize model for other north Texas communities. This methodological approach allows for collection of rich data from fewer individuals than might be possible with other methods, such as survey analysis and is strong in internal validity, but not strong in external validity due to the small sample size (Glaser, 2006).

4.4 Interview Findings

Interviews with program participants, including organizers, homeowners, city staff and representatives from the selected installation company, tell the story of the pilot Solarize Plano program from inception to completion. Concepts, including personal attributes, which influence PV system adoption among Solarize Plano participants, are identified and explored. Program features that facilitated PV adoption among participants are identified along with features that supported what seem to be reasonable and appropriate decisions for some participants not to adopt. Areas where the program may not have achieved the desired goals and where the model can be improved, especially for later "waves" of adopters, are also identified. Ongoing barriers to adoption in the study area, especially in improving the "value proposition" of residential PV, are identified. Many concepts emerging in the Solarize Plano interviews are consistent with those found in the Diffusion of Innovations and behavioral economics literature. These findings are discussed in detail below, beginning with the story of Solarize Plano's inception and structure.

Throughout the analysis, key concepts (ideas, perspectives, values that are repeatedly conveyed) from the interviews, both direct quotes and paraphrased concepts, are italicized. These concepts weave through the chapter and are summarized and contextualized in reference to the literature, in section 4.4.3.4.

4.4.1 The Solarize Plano Organizers: “*Would you mind me helping you?” “Take the plunge,” Together*

The three *volunteer* project organizers, Harold, Dave and Yori had been working together prior to the May 2013 NTREG “Solar Powering Your Community” meeting to formulate a plan for increasing solar adoption in their community of Plano, Texas. The story of how these three came to know and work together is interesting, and highlights some concepts that carry through the project in general: *Initiative* and *volunteerism*, *relationships* and *integrity*, and the *technology industry*.

As an engineering student in the 1970s when the oil embargo hit, Harold was struck by the finiteness of fossil fuels. He began to follow renewable energy technology passively as an engineering student, and gradually became more interested in renewable energy as he came to the conclusion that human caused climate change was a real concern. His interest grew to be a primary area of commitment as he shifted towards an early retirement from a career in the *technology industry*. Once retired, Harold began to *volunteer* with the *City of Plano*’s Sustainability and *Environmental* Education Division program, which is well developed and connected in the community. It was through this program that Harold *met others* with a similar interest in solar energy, began attending monthly meetings of the North Texas Renewable Energy Group to “*learn more* and *network*,” and *initiated* a grassroots effort to “increase awareness and use of Solar Energy for electricity generation in Plano (Plano Solar Advocates, 2016).” Harold was encouraged by City staff who offered to support his grassroots effort, “Plano Solar Advocates,” where goals overlapped.

It was also through volunteering with the City that Harold met representatives from the Plano based PV installation company that had installed Dave's PV system in 2009. This same contractor would later win the bid issued by Solarize Plano participants to install project systems. I would say that this is a coincidence, except that it is not. Representatives from this company had been very active in promoting solar in Plano, including *volunteering* to teach area high school students about renewable energy and attending NTREG and eventually Plano Solar Advocates *meetings*. After getting to know Harold and Dave, both retired engineers with a passion for solar energy, the owner of the company encouraged them to meet one another. This series of connections reflects the type *of community relationships* that build upon and support each other, and are strengthened by *integrity* and *professionalism* that engenders *trust*. These types of relationships are a common thread in the Solarize Plano story.

Upon the suggestion of their mutual acquaintance, Dave attended a Plano Solar Advocates meeting and quickly "*jumped in*" to assist Harold with his work to increase solar in Plano. Dave had initially become interested in solar electricity to "*offset utility bills*" and for *environmental* reasons. He installed the first phase of his PV system in 2009, at a time when there were very few installers in the region, and experience was limited for all involved. Like Harold, Dave had retired early from the *technology industry*. He decided it was time to "get out and do other things," and quickly became focused on solar energy.

Not long after Dave and Harold began working together, Yori also joined the team. Unlike Harold and Dave, Yori did not have a background in the technology industry, but had worked in real estate for many years. She did, however, grow up in a country that has been a global leader in the *electronics industry* and where solar energy technology was a visible and cultural *norm*. Her hometown, in fact, was near the corporate headquarters of a solar industry *pioneer*. After moving to north Texas, and experiencing *high electric bills* due primarily to the hot summers, she and her husband embarked on several years of *efficiency improvements* to their home. She *educated herself* along the way, became increasingly interested in renewable energy and began attending regular NTREG *meetings*. While a reserved individual, Yori has tremendous *personal initiative*. After hearing Harold speak about his goals for increasing solar energy in Plano at one of the NTREG meetings, she approached him and asked, "*Would you mind me helping you?*" So began the triple partnership of highly committed volunteers, willing to "*take the plunge*" necessary to develop and implement the Solarize Plano program.

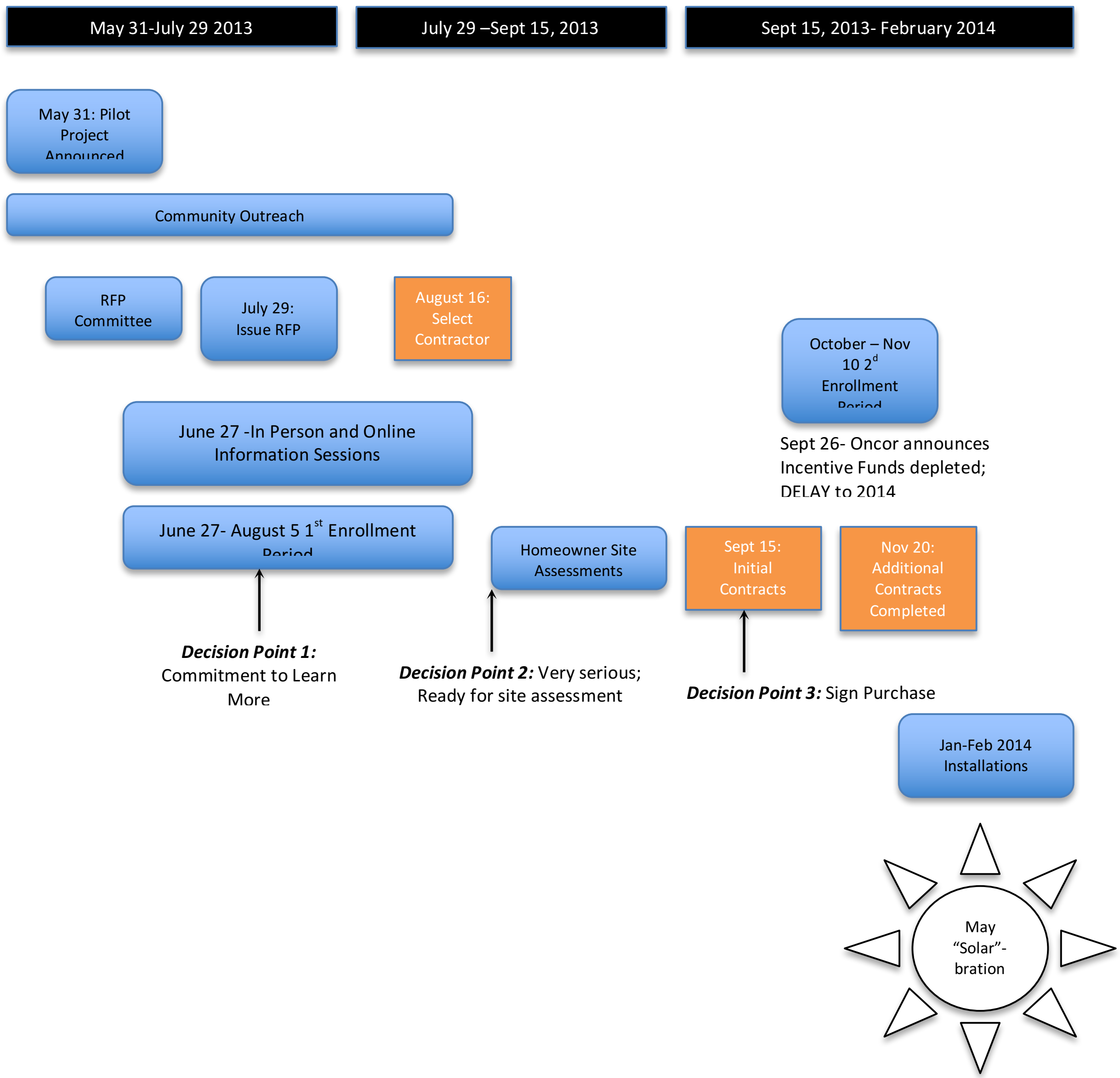
4.4.2 The Solarize Model comes to Plano: *"Why don't we just try this Solarize thing?"*

Within a few months of joining forces, Harold, Dave and Yori attended the May 2013 NTREG meeting together, seeking resources for increasing solar adoption in Plano. They had been researching San Antonio's "Bring Solar Home" program, and were planning to bring that model to Plano. However, at the NCTCOG meeting, the organizers were impressed by the presentation about the Solarize model, its success in several communities, and the revelation by Oncor staff that a large pool of solar rebate funds were being underutilized at the time. These factors, along with the availability of a Solarize "how to" manual, served as strong "catalysts" for moving forward with the Solarize model. On the drive home from this NCTCOG meeting, Dave said, "Why don't we just try this Solarize thing?" In the coming weeks, the pilot Solarize Plano program was developed and launched, and by February 2014, 20 GPV systems were installed at Plano residences, through the pilot project.

Once the trio decided to follow the Solarize model, Dave took the lead in setting goals and outlining a rough timeline that followed the Guidebook model. Yori agreed to research the Request for Proposals (RFP) process and draft RFP guidelines and a model RFP document, and Harold led the outreach efforts including designing maintaining a detailed a webpage hosted on the Plano Solar Advocates website. Yori also organized promoting the program in the *Plano Star Courier* (the *Dallas Morning News* also later covered the project). City staff agreed to promote the program in their electronic newsletters, the printed *Live Green in Plano* newsletter, and utility bill inserts, and to host informational meetings at their Environmental Education Center. Interestingly, "Dawn," who served as City staff support to the pilot Solarize Plano program, began her career with the City through volunteering for the Sustainability and Environmental Education program. She is a self-proclaimed "science nerd," who majored in Environmental Studies. Over the course of involvement with Harold and the Solarize Plano project, Dawn and one other city staff persons began attending NTREG and Plano Solar Advocate meetings as interested residents.

Figure 13 illustrates the basic project model, including the modifications specific to Plano. Figure 14 details the major programmatic milestones. As seen in Figure 13, the program was announced within weeks of the organizers attending the May 20th NCTOCG meeting, and outreach began immediately. Outreach included the launch of a program webpage, publicity through electronic and paper media as described above, and a series of information sessions intended to guide people through various steps in deciding whether or not to install PV.

Figure 13. Major Program Elements for Pilot Solarize Plano Program



The webpage included background information on photovoltaics and an online "enrollment" link indicating a "yes" to "Decision Point 1 (see Figure 14 below)." This website continued to serve as a hub for information, resources, and communications throughout the project. At the time of writing (May 2016), all project communications, timelines, presentations and other resources are still available on the Plano Solar advocates website and are free for individuals or other communities to utilize (PSA, 2016).

Figure 14. Solarize Plano Decision Points

Decision Point 1 (DP1): After learning about the Solarize Plano Project, decide whether to enroll at the project website. This is NOT a commitment to buy, but a commitment to learn more.
Decision Point 2 (DP2): After participating in the project information sessions, learning about PV solar, home orientation and shading considerations, roof age and building structure considerations, potential PV solar system sizes (in kW) that meets your objectives, and estimated system costs and calculations that affect installed costs, you must make the decision to proceed to the next step of having the selected solar company perform an on-site assessment and provide total system installation quotation.
Decision Point 3 (DP3): After receiving and reviewing a quotation from the selected solar company, understanding the range of final prices based on the final project total capacity, arranged funding, then the final decision to sign the contract with the solar company to proceed with installation.

Source: Plano Solar Advocates (2014).

Once enrolling online, which indicated an interest to learn more about solar, participants received an email encouraging them to complete "a homework assignment (PSA, 2013d) " prior to attending an information session (PSA, 2013e), and to review the decision points (in Figure 14) and a general "Frequently Asked Questions" document. The homework walked participants through calculating the size of a PV system (in kW) necessary to generate or offset different portions of their household electricity consumption: 1/3 (33%), half (50%) or 2/3 (67%). To complete this homework, participants needed to obtain their average annual electricity consumption from past bills or from their transmission and delivery utility (contact information was provided), and input this information into the formulas provided.

Four in-person and two conference call information sessions began June 27, 2013. An "on demand" YouTube information session was created at the end of July (PSA 2013b & 2013c). Ideally participants would have enrolled online and completed their homework assignment prior to participating in the information sessions, but a few enrolled afterwards. Information sessions were aimed at helping attendees understand the basics of how PV systems work; what to realistically expect in terms electricity production, system costs, and energy savings; how to assess whether they should move forward with getting a site assessment; and what to expect from participating in the program. The YouTube "on demand" information session, which reflects concepts also presented at the in-person sessions, includes information on site requirements (a minimally shaded south facing roof, in good shape); expected electricity production from PV in the Plano area based on the PV Watts online estimator from the National Renewable Energy Laboratory (1404 kWh/year); and expected ranges for pre-incentive ($3.25-$4.25/W_{DC}) and post incentive ($1.40-$2.10/W_{DC}) installed cost. Also presented were examples for how to relate typical (small, medium, and large) PV system sizes to one's average annual electricity consumption (examples given used 10,000 kWh/yr.) to estimate avoided electricity costs; options for financing a system, including the City's Smart Energy Loan Program; and considerations such as net metering/buyback rates, dealing with HOAs, adding PV to homeowner's insurance, and property tax exemptions (PSA, 2013b & 2013c).

Project organizers presented a "conservative" approach for estimating cost savings over the warrantied life (25 years) of a system. In interviews, organizers expressed a strong preference for presenting electricity cost savings in terms of levelized cost, or average cost/kWh over the warrantied life of the system, versus estimated “payback” period, or the number of year’s one expects it will take for annual electricity cost savings from the system to equal the initial investment cost. In the minds of project organizer’s, while commonly used to evaluate investment in a GPV system (see section 4.5), payback period estimates rely on highly variable inputs. Given conservative assumptions about PV production in the project area (1400 kWh/ kW_{DC}/year) and a realistic range of retail and post-incentive installed costs, organizers presented a likely range of levelized electricity costs for PV produced electricity as $.04 - $.06/kWh for 25 years for participants (slides excerpted from on demand session in Appendix D). The actual levelized cost could not be estimated until the installation prices were established with the selected contractors. Considerations for a financial analysis of residential GPV will be further discussed in section 4.5.

Project enrollment was originally scheduled to remain open until August 31, with a goal of 20 enrollees. This goal was met in early July, and the enrollment period was closed on August 5th. All system contracts were originally expected to be completed by the end of September 2013, with permits and incentive paperwork submitted by October and installations completed before the end of the year. As can be seen in both Figures 13 and 15, this timeline was delayed. Programmatic adjustments resulted from an unexpected problem with the Oncor incentives program. Solarize Plano program organizers and installers had been working closely with a program manager from Oncor, the utility company serving most residents in Plano and responsible for issuing solar rebates.

Figure 15. 2013 Pilot Solarize Plano Project Timeline

• **May 31, 2013**	**PILOT PROJECT ANNOUNCED**
• June 27	**INFORMATION SESSIONS.** Held first information session for Enrollees – In person meetings: June27; July: 22, 25, Oct 21 – Conference Calls; July 30, 31 – On demand (You tube) conference calls available beginning Aug 2
• July 8	Surpassed pilot project enrollment target of 20 enrollees
• **July 29**	**REQUEST FOR PROPOSALS (RFP)** Issue RFP (Request for Proposal)
• August 5	**ENROLLMENT PERIOD CLOSED** AND **DP2** (had originally been planned for August 31, 2013)
• August 7	RFP responses due
• August 12	Two shortlisted companies selected
• August 15	Shortlisted company interviews - August 14
• **August 16**	**SOLAR COMPANY SELECTED**
• **September 15**	**CONTRACTS SIGNED (DP3)** (Original) by this date with individual customers
• Sept 26	Oncor indicated Oncor incentive likely same in 2014, recommended shift in timeline to use 2014 funds.
• Sept 27-Oct. 31	2nd ENROLLMENT PERIOD.
• November 10	DP2 for 2nd enrollment.
• **November 20**	**CONTRACTS SIGNED (DP3- Additional)** by this date (2nd enrollment); **ONCOR INCENTIVES SUBMITTED** for all contracts by installer; Participants receive 2014 Oncor Host-Customer agreement and interconnection application to sign
• **November 25**	**DEPOSIT PAID** (20%) Cash buyers pay 20% deposit
• December 2-6	**PERMITTING-** All projects submitted to City of Plano
• **Jan-Feb 2014**	**INSTALLATIONS COMPELTED**
• **May 10 2014**	**SOLARBRATION**

Notes: Major milestones in bold.
Source: information from Plano Solar Advocates (2013a)

In late August, the Oncor representative notified the installer that solar incentives had been suddenly and unexpectedly depleted by a couple of large projects. The Oncor representative encouraged participants to submit applications for the 2014 incentives program, which she felt confident would be offered at a similar rate. Project organizers and installers felt that the Oncor representative was supportive of the project. They appreciated that the representative not only was willing to come to the meeting and speak directly with participants, but also that the Oncor "honored" their word to maintain the rebates at the same level for applicants.

Due to the delay, project organizers re-opened enrollment for the month of October. All contracts were signed by November. Systems were installed from January through February of 2014, with a "Solarbration" in May. In total, 201 people enrolled online (DP1), 52 site surveys were completed (DP2), 25 contracts were signed (DP3), 20 systems were installed (Figure 16). Five people dropped out due to a variety of factors including: not being in Oncor territory (see "No"s below), illness, and relocation. Who participated? Who adopted and who did not? Why or why not? What worked about the program and what could be improved? The following sections summarizes answers to these questions as extracted from participant interviews and socio-demographic questionnaires completed by participants.

Figure 16. Summary Outcomes of the Pilot Solarize Plano Program

- 201 enrolled
- 52 site surveys
- 25 contracts
- 20 installations

= 102.6 kWDC

Source: Plano Solar Advocates, (2014, May 10) and interviews

4.4.3 Pilot Solarize Plano Program Homeowners: Who they were and why they did or did not adopt

Two hundred twenty-one people enrolled into the program online, expressing an interest in learning more about the program and installing GPV on their home. Of these, twenty homeowners ultimately installed GPV and 181 did not. Sociodemographic information was collected along with other information as a part of the twenty interviews with adopters and non-adopters, with a higher proportion of program adopters (50%) represented by these data than program non-adopters (6%). As can be seen from Table 16, the adopters and non-adopters interviewed, are highly educated (16-36% more participants have Bachelor's Degree or higher than the mean for the the highly educated Plano), financially secure (80-90% are at or above Plano median household income which is already 42% above the DFW mean), with a majority from technological professional backgrounds. In addition, compared to Plano, whites are overrepresented and Hispanics are underrepresented among project participants' race identification in general.

Table 16. *Socio-demographic Measures for Solarize Plano Participants and Other Scales*

	Adopters	Non	Plano	DFW	Texas	U.S.
Median Household Income						
>80,0000/yr (highest option)	90%	80%	$82,484.00	$58,031.44	$51,900.00	$53,046.00
Bachelor's Degree or Higher	70%	90%	54%	25%	27%	29%
Advanced Degree	50%	50%	-			
Profession						
Engineer	40%	20%	-			
IT	20%	40%	-			
Other Science	0%	10%	-			
Finance/investment/Insurance	30%	20%	-			
Other	10%	10%	-			
Race Identification						
White/Anglo American	70%	80%	58%			
Black/African American	10%	0%	8%			
Hispanic	0%	0%	15%			
Asian	10%	0%	17%			
Other	0%	10%	2%			
Don't Know	0%	0%				
NA or Did not answer	10%	10%				

Source: Solarize Plano data from interview questionnaires; other scales where presented dare averages from from U.S. Census (2014a, b)

4.4.3.1 The "Yes"es

4.4.3.1.1 Who they are: "*Involved*," "*techno geeks*", "*on the slide*" with "*capex*"

The ten interviews with participants who chose to install PV systems as a part of the pilot Solarize Plano program reveal several common themes, some of which differentiate this group from those who did not ultimately purchase, as well as from perhaps those in the broader population, and also point to important programmatic lessons. By and large this is a group of highly educated, technically savvy, and financially secure people, who came to this project already eager to install PV if they could validate this decision. These are people who had been actively researching solar, many for several years, and in the words of one adopter, were "on the slide" when they came to the Solarize program "and someone poured Crisco all over it in the hot sun."

Adopters generally are the type of people who "*get involved*" whether in the Solarize Plano project (four of those interviewed served on the committee to select the installer), in other groups to promote renewable energy (two have participated in the North Texas Renewable Energy Group), in their churches, in their HOA, or in politics. Four of the ten adopters (40%) are *engineer*s (two are retired), two (20%) are in IT/software development; three (30%) participants are in finance; and one is a retired educator with a spouse in finance (one of the spouse participants). Nine of 10 adopters (90%) had a total family income of at or above the mean for Plano, selecting >$80,000 (the highest option choice given), with one selecting $71,000-$80,000. This is important, given that Plano, has a median household income that is 42% higher than the that for the region. The highest educational degree reported among adopters are as follows: associates (2), bachelor's (2), advanced degrees (5), with one response not clear. Seventy percent of adopters have a bachelor's or higher, which is 27% greater than the highly educated Plano, 180% greater than the region, 159% greater than Texas, and 141 % greater than the U.S. One participant self-identified as Asian, one as Black/ African American, 7 as White/ Anglo-America, and one did not answer.

4.4.3.1.2 Why they installed: "*It made sense," "no brainer"*

Most "Yes"es had been actively interested in solar for some time, for various reasons including: environmental, "independence" from oil and/or oil-generating countries, or from utilities and the associated costs. Not all adopters considered themselves environmentalists; some participants described themselves as “mother nature lovers” and “earth kids,” while a few considered themselves “not green by any means.” Most fell somewhere in the middle, looking for economic factors that would support an investment that “*was the right thing to do*.” *Energy self-reliance* was a motivating factor for a few adopters both in terms of independence from non-domestic oil-producing countries or from the utility companies.

Regardless of the initial reasons for interest in solar energy, *all* adopters interviewed stated that they ultimately purchased the PV system because they felt that the investment “*made sense*” *financially*. Several, in fact, felt that the decision was a “*no brainer*,” and honestly could not understand how anyone with a good solar site, would choose not to purchase when presented with the cost and financial facts. High up front “*capex,*” the capital expenditure required to purchase the system, was widely recognized among adopters as the only rational reason for not investing, and none considered leasing or financing a system a great option. Many, in fact, expressed a clear aversion to the lease model where “someone else has something bolted to *my property*,” and to financing unless no other option was available, as financing changes the “*value proposition*.” None of the adopters financed their system; all paid outright.

Adopters used or referred to various methods to evaluate the financial “sense” of their investment in PV, including simple payback, return on investment (ROI), and net present value (NPV) analysis, and included factors such as avoided energy costs over time and buyback rates for electricity. None relied solely on the levelized cost presented by project organizers. It was clear that there were differences among adopters in methods, assumptions, data and methodological sources for estimation as well as some confusion over concepts relevant to the financial picture such as buyback rates. Generally speaking, however the adopters expressed a level of comfort with a payback period of 9 to 11 years that was estimated by the installers in most customer proposals. Additionally, many were excited by the prospect of "*free energy*" after the payback period. Variation in logic, methods, expectations and real system performance and energy costs will be analyzed in section 4.5 below.

4.4.3.1 The Determining Factor: *Incentives*

Essential to the financial case, specifically mentioned by *all* interviewed were the Oncor *incentives* which substantially reduced up front purchase/installation price, and the 30% Federal income *tax credit* which for which adopters qualified at tax filing the year of system installation. Several adopters clearly stated that these incentives were the "determining factor," without which they would not have adopted. Monthly energy cost savings, "free energy", and *reduced installation costs* achieved by the *group purchase* were also consistently mentioned as important to the financial picture, although at least one participant was not "convinced" that the group purchase achieved notable cost savings. Whether evaluating in terms of payback, ROI or NPV, all adopters considered the incentives crucial to their decision to adopt and doubted they would have installed "at this time" without them.

4.4.3.1.4 Contributing factors: *Trust,* "*in this together*," "*easy"*

Adopters commonly mentioned several additional factors that supported their decision to purchase a PV system through the Solarize Plano program. These can be summarized as:

participating in a *group*, led by *knowledgeable*, *organized* and committed *volunteers*, endorsed by the *city*. Many felt that participating in a *group* allowed the entire process to be more efficient, simple and "*easy*" overall. They appreciated the *group vetting* of information and installers, rather than having to do all of this "*on their own*". In the words of one participant, echoed by many, "*I wouldn't have even known where to start*."

Knowing that the program was led by *volunteers* and endorsed by the City put several participants at ease that this was "not a pyramid scheme," or some other effort to "*sell something*." Participants appreciated the level of knowledge, preparation, and organization provided by the organizers and the installers. The word "*professional*" was used to describe both the volunteer organizers and the installers, who participants felt "*gave them a clear picture*," and "*walked them through*" the process "*each step"* of the way. Adopters were generally very *familiar* and *impressed* with the organizers and the sales representative and installation crew from Axium, frequently mentioning by name Harold and Dave who were most actively "in front of the room," and "Aaron [name changed] from Axium," who managed site visits, proposals, contracts, inspections, and follow-up.

4.4.3.1.5 Satisfaction: "*very pleased*," *"best looking electric bills on the block"*

By far, most adopters were very pleased with the overall experience ("wouldn't change a thing") and their decision to adopt ("*no doubt*", "a *decent decision*", "the *results are awesome*"). Importantly, most felt they would not have installed PV "at this time" without the Solarize Plano program. In the words of one adopter, "without Solarize Plano, I'd still be watching the sun hit my roof and not taking advantage of that resource." Participants generally expressed that the process, especially selection of a trustworthy installer, would have been sufficiently difficult and time consuming, and that without the program they would have been unlikely to proceed, at least in the near future.

Participants had lived with their systems for 6-10 months at the time of interviews, and most looked forward to reviewing a full year's worth of data on PV production or energy cost savings. Eight of the ten participants used the Enphase "MyEnlighten" online reporting tool that reports hourly, daily, and monthly PV production as relayed from the micro-inverters used on most of their systems. One participant, without a technical background, had access to this system but preferred to hand-log data weekly from his utility provided electric meter. Another participant, with an IT background, preferred writing his own software program to track his system performance, and another whose system did not include micro-inverters tracked via his central inverter.

Participants reported a range in their "tracking" frequency, with several tracking PV production more frequently at the beginning and less frequently over time. None reported closely tracking energy cost savings as tied to PV performance, but were generally aware, excited, and proud to see a notable reduction in monthly billing totals: "*My electric bills are gorgeous…I've got the best looking electric bills on my block*;" "our electric *bills are incredible*;" every month, "my wife says '*Oh my Gosh!*'" Fifty percent specifically felt confident that their system was producing more electricity than expected, and that "it appears that it has been a better investment" than expected. Data on 12 months of PV system performance and energy costs was later collected, and is analyzed in section 4.5 below to see how actual PV system performance and economic savings compares to participant expectations.

4.4.3.1.6 Neutral: *Aesthetics*

Several adopters alluded to the aesthetics of PV systems, although this group expressed a fairly neutral to positive perception of GPV aesthetics, with descriptions ranging from "aesthetically reasonable," to "it looks sleek." It is interesting to note, however, that several mentioned that their system was not visible from the front of the house.

4.4.3.1.7 Adopter Problems/Dissatisfaction: "Give me someone with a clue"

The most significant area of dissatisfaction reported among adopters was difficulty enrolling in a buy-back rate with their Electric Service Provider (ESP). Adopters consistently expressed having a very *difficult* and *frustrating* time getting enrolled on a buy-back rate with either Green Mountain Energy, or TXU, the only two ESP's identified as offering to buy back excess electricity production at the time of the pilot project. Green Mountain offered to buy back at a rate equal to the rate they charged (1 kWh sold= 1 kWh purchased) up to 500 kWh/month, and TXU offered to buy back at a reduced level (approximately 30% lower than their retail rate); the "net" between electricity purchased from the ESP and sold to the ESP is billed at the end of the month. Most adopters chose to "wait out" their existing ESP contracts before switching providers to one with a buyback rate, to avoid a fee.

Adopters commonly experienced customer service agents that were either *not aware* that their ESP offered such a plan, or were not aware of how to enroll a customer. The process often took several months, and required customers to call back multiple times before reaching someone who was familiar with the buyback rate and able to get them properly enrolled.

According to Aaron from Axium, one needs to "put on your *patience slippers*" when calling the ESP's to enroll in a buyback plan.

Additionally, Green Mountain apparently went through a billing system change in the months following Solarize installations, and lost several months of buyback credit information. One participant described the process as "*super broken*." While the process of enrolling in a buyback rate was touched on in both the information sessions and the "Solarbration" presentation, the process and the implications for cost analyses were not addressed in depth (see section*). This seems to have contributed to the general confusion about the role of buyback rates. At least one adopter interviewed had not yet enrolled in a buyback rate, and seemed *unclea*r of how that might impact the financial analysis of ROI or payback.

4.4.3.1.8 Adopter Problems/dissatisfaction: "*Very disappointed*"

Two adopters interviewed brought up additional concerns not mentioned by other adopters. One adopter was "very disappointed" in the amount of electricity produced by his system. He felt that the system was not producing as much electricity as he had expected. He was particularly disappointed that there had been only "one day" where he "had maximum power generated" by his system. This was not clarified further, but gives the impression that this participant was expecting to see the power indicated by the "maximum power" rating of the system, a number that does not correlate to actual production values. Program organizers presented an estimated 1400 kWh/yr per installed kW_{DC} as a realistic expectation for Plano. This number (from NREL's PV Watts estimator tool) includes system inefficiencies and geographic considerations such as climate and solar insolation. It is important to note, that even though this participant felt his system was underperforming, he also seemed unclear as to whether his payback would be lower than expected. He also generally expressed a passion for renewable energy, remained *active in promoting* solar, and voiced the opinion that "one would be *silly" not to use solar* energy if they could.

Another adopter was extremely disappointed in the inability to use PV electricity during a power outage. Despite being told throughout the process that a battery backup option was not being offered as a part of this program, he remained convinced until the day his system was being installed that he was "going to get what [he] wanted (a battery backup)." These sentiments were widely echoed by non-adopters, as will be discussed below. In fact, this participant could be categorized as an "accidental adopter," who was much more motivated by self-reliance than by potential cost savings.

4.4.3.2 The "No"s

4.4.3.2.1 Who they were: *Careful Adopters*

The 10 interviews with participants who chose not to install PV systems as a part of the pilot Solarize Plano program reveal common themes, some of which differentiate this group from those who did purchase PV, and also point to important programmatic lessons.

Like the adopters, this is a group of highly educated, technically savvy, people with relatively high income levels. Consistent with the adopter group, the highest educational degrees reported are as follows: 1 associates, 4 bachelor's, and 5 advanced degrees. Most of this group also has either technical or scientific backgrounds, but unlike the adopter group where 4/10 (40%) are professional or retired engineers, this group has more representatives

(5/10) in information technology (IT) and one systems engineer. One of the IT professionals also has an advanced degree in physics and mathematics, one participant is a geologist, one is a commercial real estate investor, and one is a retiree who identifies as a farmer. Eight of 10 (80%) have a total family income of >$80,000 (the highest option choice given), with two selecting $71,000-$80,000. Eight participants (80%) identified themselves as White/ Anglo-America, one identified with several racial categories listed, and one did not answer.

Like adopters, the non-adopters largely had been considering solar for a while, for a variety of reasons, including potential *economic savings*, *independence*, and *environmental* reasons. This group can be broken into two sub groups: the "Yes but No's", and the real "No's."

4.4.3.2.2 The Yes but No's

There were two non-adopters who were very similar to the group of adopters: they entered the process *ready to install*, and had decided early on that it "*made sense*" for them, but ultimately could not install due to problems with their distribution utility, CoServ, or with their site. One couple interviewed represented apparently a handful of participants whose distribution utility was CoServ rather than Oncor. While Oncor has run a fairly steady incentive program since 2008, with rebate rates and structure in line with other utility programs across the country, CoServ had a rather unconventional rebate structure, which changed during the Solarize Plano pilot program. Rather than offering a standard rebate incentive amount in dollars per installed watt, subject to performance standards (usually solar orientation and shading) and a rebate cap, the CoServ rebate had been set for several years at a flat $5,000 per system, regardless of size in kW.

CoServ announced a new incentive structure during the contracting period for the Solarize Plano program, which shifted to a flat amount of $1000 per system, and included an interconnection fee and monthly charges for grid-connection. Essentially, these changes dramatically altered the "value proposition," such that Axium let all CoServ customers out of their contracts, acknowledging that installing with the new rebate structure and fees "*doesn't make any sense*." CoServ's changes as well as their reaction to participant emails, letters, and calls, were perceived by the participants as an effort to dissuade and inhibit people from installing solar.

Two other participants chose not to install for site reasons. One was clearly a "Yes" that could not install unless they chose to cut down "two absolutely gorgeous trees," which they were unwilling to do. The second, would have had to extensively modify his garage in order to create an adequate area for installation. This would have required a "political fight" with the HOA of which he sat on the Board, and added substantial expense to the project. He did not feel that the financial or political cost justified his investment in a system that did not perfectly suit his needs. He also wanted to be able to use his PV system, when the power was out (see "Independence: a deal breaker" below).

4.4.3.2.3 The Real No's: "*On the fence*" and "*needed more*"

Like the adopters, this group was also evaluating whether or not installing a PV system would make sense. However, unlike the adopters who were by and large "primed" and ready to install given fairly basic justifications that this decision "made sense" financially, this group seemed generally earlier in their decision making process than those who adopted, were not necessarily bought into the idea of the GPV system prior to participation, and were still deciding if the technology itself was right for them. In line with Roger's Diffusion of Innovations theory, this groups needed more uncertainty reduction than the adopters, specifically *more information* and explanation especially regarding financial analysis, and felt that they needed "*more time*" to make their decision. In particular, several felt that they did not have enough time or information to make the commitment they felt was necessary to receive a site visit (DP2).

Participants from this group generally expressed that the Solarize Plano organizers and installers (for those who received site visits) were *professional*, *organized* and *prepared*. However, the language used by several non-adopters to describe information sessions, such as "they gave their spiel," or "their pitch," reveals an underlying *skepticism* not evident among adopters. Also non-adopters seemed generally less familiar with program organizers than adopters. While adopters repeatedly refer to the organizers by name in interviews, non-adopters often could not get the organizer's names quite right.

4.4.3.2.4 *"It just didn't make sense."*

The most common reasons for not installing were economic considerations. The high "*capex*," or capital expenditure required, combined with *too long of a payback period* were very important concerns. Many non-adopters expressed concern about *moving prior to recouping their investment* through energy savings, and unlike adopters felt *uncertain* that they would recoup the investment during *resale* of their home. *Competing economic priorities*, including home upgrades and repairs, and children's education, were commonly discussed.

Overall, this group evaluated the financial sense of this investment differently than the adopters. There was a stronger sense of the *financial impact* of this investment among non-adopters, with several participants making statements such as "it's *not an inexpensive process*," and "I think most people doing this have got a lot of *money to spare*." Several came into the process hoping for a shorter payback period than was realistic at the time. Whereas adopters found 9-10 years to be reasonable or even "a good deal", this group was generally hoping for a shorter payback of 3-5 years. For some of those who had hoped for a payback of 3-5 years, the process worked rather efficiently to inform them that their expectations would not be met and that solar was not an appropriate choice for them at this time. However, there were several who did not understand the payback period until receiving a site visit, partially due to the reluctance of organizers to present potential savings in terms of payback period. It is clear that several non-adopters did not fully understand the information on financial considerations as presented, and some pulled out of the process prior to gaining clear understanding. This will be further discussed in section 4.5.

Additionally, it is unfortunate that the income ranges provided on the socio-demographic forms only went up to ">80,000." It is anticipated that many participants, both adopters and non-adopters, have substantially higher household incomes. Providing more income brackets, may have indicated some income differences between the two groups.

4.4.3.2.5 Independence: "*A deal breaker*"

The inability to use PV power during a power outage was described as a major factor, even a "deal breaker," for non-adopters. These people valued independence and thought it was “bullshit” that they would spend such a large sum of money and not get to use “*[their] sola*r” during a power outage. “I mean you’ve got 10,000 watts on your roof and you can’t use it, I say what the hell is it good for?” Many did not understand why conventional backup generators were permitted for use in a power outage, but not GPV, and found any explanation to be “*bureaucratic babble*” that “*makes no sense*.” This group’s anger at being prohibited from accessing their “own power” at any time is a manifestation of “independence” as a character trait, which manifests differently for adopters, as described in section 4.4.3.3.

4.4.3.2.6 “*Aesthetics*”

Aesthetics were definitely a factor for many participants who did not adopt, which was often revealed in conversations about the real or anticipated reaction from neighbors, friends and/or spouses. Clearly, the perception of system aesthetics was more important to this group. One non-adopter stated that aesthetics and other financial priorities were the two top reasons for not adopting. His wife was “not thrilled,” with the aesthetics which he said “aren’t the most attractive thing in the world.” Another non-adopter described the roof location where he had initially hoped to install, as being in the back of the house, which would “not be offensive for the [other] homeowners.”

4.4.3.3 Adopters and Non-adopters: *Energy Self Reliance*, *Independence* & “*Public Enemy Number One”*

Throughout adopter and non-adopter interviews, an interesting tension was noted, that seems to stem from the adaptation of a technology rooted in the “off-grid” energy self-reliant culture, for a grid-interconnected application. Several adopters and non-adopters referenced "self-reliant" values and exhibited "independent" characteristics. Among adopters this was primarily expressed as an aversion to financing and preference to "*owning my own stuff,*" and a desire to receive a "*fair*" treatment from the utilities in terms of buyback rates. This tension was made apparent by one "independent" minded participant who seemed to be justifying his acceptance of the utility incentives, "it's really *our money* anyways."

As discussed in the literature, both ESP's and transmission and distribution utilities (TDU's) have generally responded to the emergence of GPV as a threat to their business model, moving slowly to remove barriers to grid access, or even at times overtly putting additional barriers in place. Most recently, an industry-coordinated effort has emerged to resist expanded access to the grid. Increasingly, utilities are justifying new or increased grid access fees for customer-sited PV, as necessary to provide grid services in a "fair" manner. As was experienced among CoServ customers in Plano, these type of fees can greatly impact the cost effectiveness of GPV.

With the Solarize Case study, this tension between customers and both ESPs and TDU's was indicated by the presence of only two ESP's providing rather inadequately run buyback programs, and CoServ's incentive program that, in the words of the CoServ participants, indicated "*they did not want us to do this*."

Importantly, the adopter experience indicated that Oncor's approach at this time was supportive of GPV. This may be due to the fact that investor owned utilities in Texas receive credit towards State mandated renewable energy requirements, by providing such incentives. It also appears that the Oncor culture, at least in the study area, is receptive to interpersonal connections and communication as indicated by the participation of high level Oncor staff in meetings with Solarize Plano installers, organizers and participants, and by the willingness of Oncor staff to share information with the researcher through email and telephone dialogue.

There were a couple of Oncor customer-adopters who were aware of, and vocal about, recent efforts on the part of utilities in general to charge GPV customers for "grid access." One adopter in particular strongly resented the attempt on the part of utilities to "*demonize*" solar producers, and almost seemed proud about being "*public enemy number one*" to the utilities who he sees as being stuck in an outdated business model. Several felt that the utilities will need to adjust to a "*new business model*" where "*pro-sumers*" are paid fairly for the electricity they produce and for their contribution to grid efficiency. The sentiments are articulated by both the CoServ adopter, who felt that CoServ "should be embarrassed" about their policy, and the Oncor adopter's stance:

> There's an effort here to punish and demonize people who are doing something that is absolutely common sense…the power providers and distributors are not gonna make me feel guilty about using solar energy. They're just not. I'll look them right in the eye and say, 'I'm sorry, you're gonna have to find another way to make a buck.'

This tension will certainly continue to be a factor, especially the value proposition for customers, in GPV adoption. The role of customer-sited battery storage will be an important part of the utility/customer "pro-sumer" relationship.

4.4.3.4 Summary of Interview Concepts

Tables 17 and 18 summarize the key concepts identified through interviews with Solarize Plano homeowners, organizers, staff and installers. Table 17 summarizes the specific concepts described above as relevant to adoption and the Solarize Plano project. Table 17 highlights the concepts identified in adopter-centered literature described in Chapter 2, that were also found to be important among Solarize Plano interviewees, as supported by the more specific concepts summarized in Table 17. In Table 18, concepts in bold indicate those that were validated in participant interviews, with those concepts found to be most relevant locally, highlighted in yellow. Important themes are further discussed in section 4.6.

Table 17. *Concepts influencing Adoption, Solarize Plano Pilot Project*

ORGANIZERS	City/Staff	INSTALLERS
highly educated technically savvy financially secure willing to jump in, initiative volunteerism passion project relationships, networking knowledgeable experienced	*trust volunteerism initiative environment relationships*	*professional knowledgeable polite walked me through each step above and beyond relationships, networking*
PARTICIPANTS		
YES	NO	
highly educated technically savvy financially secure actively researching involved ready/on the slide with capex	*highly educated technically savvy financially well off but feel less secure actively researching on the fence*	
WHY/WHY NOT		
$ made sense, no brainer incentives offset utility bills free energy group/lower price group, in this together, vetting easier environment the right thing to do sustainability is a good business model independence	*capex did not make sense payback long move prior to recoup investment other financial priorities on the fence, needed more time/information the numbers didn't add up misunderstanding of finances can't use my electricity in a power outage CoServ Trees/site aesthetics*	
SOALRIZE PLANO OVERALL		
wouldn't change a thing wouldn't have even known where to start walked me through each step of the way/easier group, relationships call Harold and Dave City affiliation, Not a pyramid scheme	*not sure how many meetings I went to "Gary and Dan" gave their spiel I needed more: time, information's didn't follow up*	
FEEL ABOUT DECISION		
very pleased best looking bills on the block' exceeding expectations	*I really wanted to do it not at this time*	
UTILITIES		
Oncor- "worked with us", "honored" their word buyback rate- Get me someone with a clue", "patience", "super broken" "We are public energy number one"	*CoServ "should be ashamed of themselves" bureaucratic babble (not allowed to use out power)*	
OTHER		
no- Financing- someone else's capital bolted to my roof my energy efficiency upgrades	*I would have had to take a loan, city loan was a joke my energy efficiency upgrades*	

Table 18. *Concepts in Literature Supported by Solarize Plano Interviews*

Top Down Perspective		End-User/Adopter Perspective	
		Technical	
Panel/component Efficiency	33	**Performance**/Trust	9,10,19,26,29
Panel/component Durability	33	Durability	10
Demand management	1,12,13,1	Complexity/lack of technical understanding	10,19,30
Grid integration	14,20,22,32	**Warranties**	10,16
Safety	15,36	Safety	10
		Structural or Legal	
Interconnection policy (+/-)	15,24,35	**Trust in Utility**	10,16
Permitting: complexity, expense, consistency	1,6,15,24,35	Time/confusion over inspections	16
Net metering policy (+/-)	3,4,15,35	**Trust/lack of clarity from Electric Service Provider**	10,16
Planning and Zoning	24,36	**HOA**	16
RPS	3,35	Legal/regulatory uncertainties	10,30
		Financial	
High Initial Cost	2,11,24,32,36	**High Initial Cost**	8,9,10,16,25,
Financing	2,24,32,36	**Financing**	23,26
Rebates/Incentives	36	**Rebates/Incentives**	8,9,10,16,18,19,23,37
No fuel costs	33	**Unclarity for estimating savings**	28
Buyback rates (also legal)	3,15,36	**Buyback rates (also legal)**	4,10,16
		Payback	10,16,30
		Reduced future energy cost	19, 30,37
		Cost of electricity	18
		Financial Implications of home sale	10
		Information	
Lack of costumer awareness/knowledge	32	**Information** sources- trust	10,21,23,26,27,37
		Lack/**Confusing**/conflicting information	10,35
		Trust	23,25,27,28,30,37
		Installer/Workforce	
Need for training	15,32	**Informed**	16,18
		Trust	10,16,18
		Environment	
Low impact	5,34,36	**Low impact**	8,9,10,16,37
		Desire to lead by example	10,16
		Energy Independence	
Domestic Energy Source	5,36	**Domestic Energy Source**	10,16
		Independence from utility	29
		Power when storms	10,37
		Self-sufficiency	10,16,29
		Other	
		Maintenance **Aesthetics**	8,9,10
		Friends/Neighbors/Others	10,21,27,30,37
		Interest in RE/Curiosity	10,16
		Responsibility or **Leadership**	10,16,19, 31
		Ease/difficulty of overall process	8,9,19,29,30

1 Alajlan, 1999
2 Ardani et al., 2013
3 Barbose & Darghouth 2015a
4 Barnes & Vernado, 2010
5 Berman & O'Connor, 1996
6 Brooks, 2012
7 City of San Diego,CSE, USDOE, 2009
8 Faiers &Neame, 2006
9 Faiers, Neame, & Cook, 2007
10 Farhar & Buhrman, 1998
11 Friedman et al., 2013
12 Hill, 1994
13 Hoff and Shugar, 1995
14 Garve, Latour, & Sonvilla, 2012
15 See all *Freeing the Grid* reports for years 2007-2014 1st author: IREC or NNEC
16 Jack Lambert, 2010
17 Kind, 2013
18 Kwan, 2012
19 Labay & Kinnear, 1981
20 Lindt, Fox, Ellis, & Broderick, 2013
21 McEachern &Hanson, 2008
22 Paidipati, 2008
23 Peter, Dickie, & Peter, 2006
24 Pitt, 2008
25 City of Tucson staff, personal communication, 2009
26 Prasad, 2008
27 Rai & McAndrews, 2012
28 Rai & Robinson, 2013
29 Rosoff, personal communication, 2009
30 Sidiras & Koukios, 2004
31 SmartPower ,2007
32 Solar Electric Power, 2001
34 Stanfield & Vanega, 2015
34 Sterzinger & Svrcek, 2005
35 USDOE, 2010
36 USEPA, 2016
37 Velayudham, 2003
38 Wesoff, 2014

4.5 Financial Expectations, Installed Costs, System Performance, and Energy Cost Savings

An interesting theme emerging from participant interviews is that both adopters and non-adopters consistently expressed a need to evaluate the "financial sense" of an investment in GPV, yet were inconsistent in their considerations, assumptions, and methods for evaluation, as well as in their level of understanding about how to conduct such an evaluation. Because the financial evaluation was identified as important to all participants, it is useful to investigate the source and implications for these inconsistencies as well as to identify some opportunities to reduce any unnecessary confusion for those developing similar initiatives.

This section elaborates on findings from the qualitative interviews described in section 4.4. Installed costs and incentives are presented for the ten adopters interviewed, and twelve months of actual electricity production, billing, and estimated electricity cost savings for pilot Solarize Plano participants are summarized and compared to expectations.

4.5.1 Financial Expectations

First, it is important to note that there was an important difference in financial expectations noted between adopters and non-adopters. This variation was noted by Aaron from Axium, who alluded to "misaligned expectations," of many non-adopters. Generally speaking, most adopters were comfortable with a 9 to 10 year payback period. According to Aaron, "a conservative estimate in Oncor area, with reasonable expectations of future energy costs is 8 to 9 years." However, 70% of non-adopters interviewed hoped for less than 9 years, with 50% hoping for shorter than 5 years. Half of the non-adopters interviewed did not realize that their expectations were unrealistic until the site visit. While 48% of site visits translated into contracts, which is substantially more “efficient” for the installer than the usual 20-25% “conversation rate” reported by Aaron, there is an indication that some of these misaligned expectations could have been identified prior to a site visit.

A second, and related, finding is that there was some confusion among both adopters and non-adopters about methods for estimating cost effectiveness of investing in GPV, with non-adopters generally seeming less clear on the impact of various inputs. While the program organizers presented cost savings in terms of levelized cost of electricity over the warrantied life of the system, or the price per kWh one would “pay” for electricity generated by the PV system over the warrantied life of the system, participants generally chose other more conventional methods to evaluate their investment, including: simple payback, return on investment (ROI), or net present value (NPV). Definitions and formulas for these three evaluation tools are presented in Figure 17.

All but one participant used a simple payback analysis, though some mistakenly referred to the simple payback as “Return on Investment” or (ROI). The one participant who used a NPV analysis had a strong background in financial analysis of technical projects. Each of these evaluation methods requires information on the capital expenditure and the expected return/inflow, which can vary depending on assumptions. The capital expenditure, or the cost of the GPV system, is fairly straightforward to identify. The “capex” will be higher if a project is financed, as with Plano’s Smart Energy loan, and can be reduced by incentives and the group purchase discount. The expected cash “inflow” from a GPV system over time is influenced by: household electricity consumption (in kWh), PV electricity production (in kWh); warrantied and actual “life” of the system or the years that PV will be produced; “degradation” of PV production, or the % decrease in performance expected for a PV system/year; price of electricity; buyback rates (the price an energy service provider pays the customer for electricity produced); and any fees/charges for distributed generation. Homeowners insurance rate increases and property tax exemptions should be considered in the overall financial evaluation as well.

Figure 17. Definitions of Common Financial Evaluation Tools

Financial Evaluation Tool	**Formula**
Simple Payback Period: " the length of time required to recover the cost of an investment."	**Payback Period=** $\frac{\text{Cost of project}}{\text{Annual Cash Flows}}$
Return on Investment (ROI): "measures the amount of return on an investment relative to the investment's cost. To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment, and the result is expressed as a percentage or a ratio."	**ROI=** $\frac{(\text{Gain from Investment- Cost of Investment})}{\text{Cost of Investment}}$
Net Present Value Analysis (NPV): "the difference between the *present value* [emphasis added] of cash inflows and the *present value* of cash outflows …A positive net present value indicates that the projected earnings generated by a project or investment (in present dollars) exceeds the anticipated costs (also in present dollars). Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss." A discount rate is used to determine the present value of inflows and outflows.	**NPV=** $\sum_{t=1}^{T} \frac{C^t}{(1+r)^t} - C_0$

Source: Investopedia (2016)

Assumptions about any of these variables can influence, sometimes significantly, the estimation of a project's cost effectiveness. It is clear that most participants did not include all of these elements in their analysis. This appears to be the result of several factors: the reluctance of project organizers to frame savings in terms of payback period or to get specific about variable inputs; the apparent limitations of some participants in understanding financial analyses, consistent with behavioral economics notion of "bounded rationality"; and an apparently lower threshold for specificity required by adopters in their analysis. Generally, adopters were satisfied with a more conservative, less detailed analysis than non-adopters, which is consistent with the finding that non-adopters consistently expressed more concern about the financial impact of investing in GPV.

4.5.2 Overview of Installed Costs, System Performance and Energy Cost Savings

In this section, information is presented on installed costs (pre and post incentive) for the ten Solarize Plano adopters interviewed. Twelve months of PV production, billing and cost savings are summarized for those participants with available data. Given that at the time of writing there were an estimated 1839 residential GPV systems in DFW, including 190 in Plano, it is somewhat surprising that little “shared knowledge” and “hard data” about system performance and electricity cost savings was publically available for the region. There is an apparent need for tracking and communication of actual system performance and correlation of PV electricity production to billing and electricity cost savings in the region. Additionally, while Solarize Plano adopters had access to software that tracks PV electricity generation, and of course receive monthly bills, none were actually calculating their real savings at the time of the interviews.

Nine out of ten adopters believed their system was meeting or exceeding expected production values, and expected to achieve better than anticipated electricity savings and a shorter payback period. Most were tracking energy production though the online “MyEnlighten” software tool that was included with their installation package, with many reporting a decline in their frequency of tracking over time. Generally, most were impressed and satisfied with the “proof” of lower monthly electricity bills. However, many also expressed an intention to look back at the data after twelve months of living with the system. This section presents data for actual PV electricity production, system azimuth and tilt angles, household electricity consumption, billing and estimated cost savings.

4.5.2.1 Procedures for Summarizing Installed Costs, PV production, Billing and Cost Savings

Adopters provided information on pre-incentive installation costs, Oncor rebates, and Federal tax incentives received. In order to summarize twelve months of PV production, billing and cost savings, all 10 adopters were emailed a spreadsheet with examples, requesting the following information:

- PV system size kW_{DC}
- Total PV production in kWh per month [this was cross checked with data from Axium]
- Energy Service Provider (ESP)
- Monthly billing total charges (includes all charges and buyback credit where applicable)
- Inflow from the grid (kWh)
- Inflow rate (electricity rate in $/kWh)
- Outflow to the Grid (kWh)
- Outflow rate (if on buyback rate ($/kWh)
- Outflow credit (if on buyback rate ($)
- Likely ESP if they had not installed

It became clear rather quickly that Axium Solar would provide a more accurate source for participant's PV production data. Axium provided 15 months (March 2014- May 2015) of PV production for nine of the adopters. One adopter had a technical issue that resulted in a loss of tracking for several months. In addition to PV production, Axium provided for each system: size (kW_{DC}), azimuth (degrees from south, with 180 = due south) and PV tilt angle. Maximum electricity production, and Oncor rebate level, is achieved with a PV system oriented within 20 degrees of due south (180^0), or an azimuth between 160^0 and 200^0, and a tilt angle (for a fixed mount system) of approximately 33^0.

Complete billing data was provided by eight participants in response to the data request. Seven participants were on a buyback rate with Green Mountain Energy or TXU, one participant did not provide any data, and another had incomplete billing and production data due to a delay in enrolling in a buyback rate, as well as a problem with his PV production tracking software. For those on a buyback rate, total electrical consumption could be calculated with the following formula, based on billing data:

Electric Consumption = Inflow + (PV production- PV outflow).

Unfortunately, it was very difficult to obtain the total electrical consumption for the remaining participant who was not on a buyback rate. Therefore, cost savings could not be accurately estimated for three participants.

PV production and billing data was used to estimate monthly and annual cost savings achieved by the GPV system (Table 20). Monthly electricity costs, had the customer not installed PV, were estimated by multiplying actual total electricity consumption (above), by the the average retail electricity rate that each participant would have likely paid without GPV. The average monthly rate for 2014 (PUCT,2014), was used for the ESP that each adopter indicated they would have used, had they not installed GPV. Monthly billing (what the adopter actually paid) and estimates (what they would have paid without PV) were totaled for the year. Annual energy cost savings were then estimated by subtracting what each adopter paid annually for electricity with the PV system installed from the estimate for what each adopter would have paid without PV. The simple payback period was estimated by diving the final net installed cost, after rebate and tax credit, by the annual energy cost savings (see Table 20). No escalation in electricity was assumed, which produces a very conservative estimate of savings.

A fuller picture would have been drawn with complete data from all ten participants who installed GPV systems as a part of the pilot Solarize Plano program. It is unfortunate that a complete billing and avoided cost estimate could not be performed for the two participants not on a buyback plan, in order to compare with those on a buyback rate.

4.5.2.3 Summary of Installed Costs, PV Production, Billing, and Cost Savings

Table 19 presents the pre and post installed costs for ten adopters interviewed, along with details on the financial incentives received. As can be seen in Table 19, the combination of utility and Federal tax incentives greatly reduced the final installed cost for each system, with an average cost reduction of 45 %. The average system size was 5.15 kW_{DC}, with the average post incentive installed cost $7,729. Also, the pre-incentive installed costs for these ten participants were on average $.25/$W_{DC}$ (7.7%) lower than for Texas and $1.1.9/$W_{DC}$ lower than for the U.S. for 2013.

Table 19. *Installed Costs and Financial Incentives for 10 Solarize Plano Systems*

SYSTEM ID	1	2	3	4	5	6	7	8	9	10
SYSTEM SIZE kW_{DC}	2.94	4.41	2.5	8.5	5.39	7.85	3.6	7.35	4.41	4.6
Pre-incentive Installed Cost	$9,526	$14,288	$7,767	$27,183	$17,464	$26,578	$12,266	$23,814	$14,288	$14,756
Oncor Incentive	$3,096	$5,644	$2,970	$9,251	$6,899	$5,332	$4,810	$8,793	$5,707	$5,958
Fed Tax Credit	$2,858	$2,593	$720	$5,379	$3,169	$5,332	$2,285	$4,631	$2,574	$2,639
NET installed cost after incentives	$3,572	$6,051	$4,077	$12,552	$7,395	$15,914	$5,171	$10,390	$6,007	$6,159
(Pre-incentive) installed cost/ W_{DC}	$3.24	$3.24	$3.11	$3.20	$3.24	$3.39	$3.41	$3.24	$3.24	$3.21
(Post incentive) installed cost/ W_{DC}	$1.21	$1.37	$1.63	$1.48	$1.37	$2.03	$1.44	$1.41	$1.36	$1.34
Mean system size kW_{DC}	5.15									
Mean pre-incentive installed cost/kWDC	$3.25									
Mean NET Incentive installed cost/kWDC	$1.46									

Mean system cost (pre-incentive)	$16,764
Mean system cost (post-incentive)	$7,547

Tables 20 and 21 present the twelve months of PV production, billing and cost savings for the Solarize Plano adopters with available data; this performance data is compared to participant expatiations. Table 20 presents system details including size, azimuth and tilt angle, along with monthly electricity production in (kWh) per installed kW_{DC} for all 10 adopter systems. Annual and monthly means are included. Figure 18 presents the annual electricity production and Figure 19 presents the monthly mean electricity production for each of the nine systems where complete data was available, in kWh/installed kW_{DC} for May 2014-April 2015.

As can be seen in Table 20, all nine systems with a year's worth of data, produced more electricity than the expected 1400 kWh/ kW_{DC}/year, with the mean for all 9 systems being more than 5% greater than expectations. On average, the PV systems installed produced enough electricity to cover 54 % of the customer's annual electricity consumption. Adopters were on target with their impressions that their systems were producing more than what program organizers and installers presented.

Table 20. *Monthly and annual PV production in kWh per installed kW_{DC} for the 9 system with complete data for May 2014-April 2015*

SYSTEM ID		1	2	3	4	5	6	7	8	9	10
SYSTEM SIZE kW_{DC}		2.94	4.41	2.5	8.5	5.39	7.85	3.6	7.35	4.41	4.6
AZIMUTH		168	180	143	269	180	238	146	175	172	187
TILT		33	39	28	33	34	28	20	38	28	32
YEAR	**MONTH**										
2014	MAY	146.26	141.95	158.00	189.41	154.36	159.24	161.35	152.38	159.12	111.73
2014	JUN	130.27	125.40	140.00	138.24	137.48	147.77	129.20	138.78	128.95	140.80
2014	JUL	138.44	133.11	152.00	144.12	146.01	150.32	154.29	142.86	156.50	150.97
2014	AUG	152.04	151.47	162.40	182.35	162.34	163.06	153.24	155.10	147.00	163.85
2014	SEP	128.23	133.56	134.00	118.47	139.52	133.76	134.16	123.13	153.84	118.65
2014	OCT	136.05	148.98	142.40	116.94	158.26	135.03	142.18	129.80	151.67	117.43
2014	NOV	106.12	119.95	108.80	113.53	126.72	103.06	101.53	101.22	116.99	NA
2014	DEC	69.05	73.47	68.80	62.94	78.29	66.24	70.13	65.03	101.23	NA
2015	JAN	107.14	117.01	103.60	88.24	121.71	100.00	103.24	96.33	124.62	NA
2015	FEB	96.26	103.63	99.20	95.18	109.46	97.58	96.37	92.38	124.18	NA
2015	MAR	96.94	105.22	106.00	81.88	107.42	102.17	102.67	99.73	86.22	NA
2015	APR	104.42	107.48	113.20	111.65	112.06	109.17	111.45	109.25	125.46	NA
MAY-APRIL TOTAL		1411.22	1461.22	1488.40	1442.94	1553.62	1467.39	1459.83	1405.99	1575.78	
MONTHLY AVERAGE		117.60	121.77	124.03	120.25	129.47	122.28	121.65	117.17	131.31	

MEAN ANNUAL FOR ALL SYSTEMS	1474.04 kWh/kW_{DC}
MEAN MONTHLY FOR ALL SYSTEMS	122.84 kWh/kW_{DC}

MEAN % OF ANNUAL CONSUMPTION COVERED BY PV	54 %

Source: Data provided by customers and and from Axium

Ironically, the one adopter who was "very disappointed" in his system's performance, had the second highest electricity generation of the group, generating 1553.62 kWh/ kW_{DC}/year, or 11% higher than the expected/presented 1400 kWh/ kW_{DC}/year, and the second shortest simple payback period of the group at 6.95 years. This participant was not an engineer, and this apparent confusion speaks to the importance of clarifying both technical and financial expectations.

Figure 18. Annual Electricity Production in kWh/ kW_{DC}

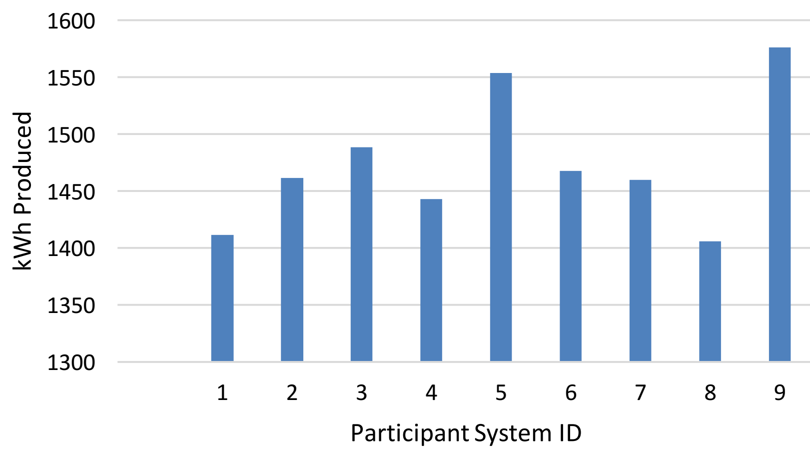


Figure 19. Monthly Mean Electricity Production for 9 Pilot Solarize Plano GPV Systems, in kWh/Installed kW_{DC}.

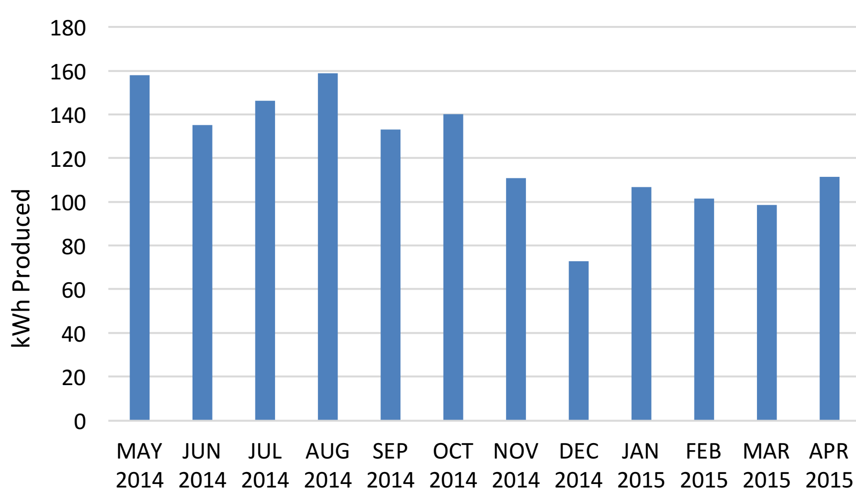


Table 21. *12 Months of PV Production, Billing, and Estimated Energy Savings for 7 Solarize Plano Pilot Program GPV Systems*

SYSTEM ID	1	2	3	4	5	7*	9
SYSTEM SIZE kW_{DC}	2.94	4.41	2.5	8.5	5.39	3.6, 5.24*	4.41
AZIMUTH	168	180	143	269	180	146	172
TILT	33	39	28	33	34	20	28

Annual PV Prod (kWh)	4,021	6,293	3,662	12,678	8,762	7,956*	6,716
Annual Consumption (kWh)	11,022	21,896	7,119	15,413	13,839	13,457	14,940
Avg. monthly consumption (kWh)	918.50	1,824.67	593.25	1,284.42	1,153.25	1,121.38	1,244.97
Annual Net Bill	$801.10	$1,836.84	$725.03	$466.01	$771.64	$755.10	$953.21
Average Monthly Bill	$66.76	$153.07	$60.42	$38.83	$64.30	$62.93	$79.43
Net Metering: GM, TXU, No	GM	TXU	TXU	GM	GM	GM	GM
Estimated Avg. Annual Bill, No PV	$1,052.88	$2,374.28	$836.77	$2,068.12	$1,835.66	$1,417.96	$1,553.80
Avg. Monthly Bill, No PV	$888.67	$197.86	$69.73	$172.34	$152.97	$118.16	$129.48
Estimated Annual Savings	**$251.78**	**$537.44**	**$111.74**	**$1,602.11**	**$1,064.02**	**$455.39**	**$600.59**
Simple Payback (years)*	**14.19**	**11.26**	**36.48**	**7.83**	**6.95**	**5.02**	**10.00**

Mean Estimated Annual Savings	**$247.03**
Mean Simple Payback	**13.10**
Mean simple payback- excluding outlier	**9.21**

Notes: *Added 3.5 KW to existing system for total system size of 5.24 kW

Annual PV production for total system, but annual savings attributed to addition (68.7% of annual savings) and this # used for payback.

4.6 Chapter Summary: Concepts Influencing Adoption and Program Success for Solarize Plano

The pilot Solarize Plano Project was initiated in May of 2013, with 20 PV systems installed though the program by March of 2014. Consistent with the experience of the Solarize models in other communities, the pilot Solarize program appears to have achieved several program goals including: increasing the amount and rate of residential GPV installed in Plano (see Table 21), making adoption easier and more affordable for homeowners, and overcoming additional barriers to adoption. Concepts influencing adoption, key program achievements and outcomes, and areas for improvement, are summarized in this section.

4.6.1 Program Metrics and Accomplishments

Table 21 summarizes the cumulative number of residential GPV systems installed in Plano, DFW, Texas, and the U.S. for the study period, along with the growth in installations from 2013 to 2014. The percentage of Plano's 2014 installations from the Solarize Plano Program are identified for both the pilot and second round (January-September 2014). Although evaluation of the 2014 Solarize Plano is beyond the scope of this research, the "installation" impact of both rounds of the program are included.

Plano saw a 127% increase in residential GPV systems from 2013 to 2014. This compares to a 114% increase in the region, and only an 8% increase in Texas and a 30% increase in the U.S. over the same time frame. Twenty percent of the systems installed in Plano in 2014 were from the Solarize Plano pilot project, and 22% were from the second Solarize Plano program (2014). In total, 44 % of the systems installed in Plano in 2014 were from the combined Solarize Plano projects (pilot and 2014). Applying the GHGs emissions factor for the ERCOT region, in

Table 22. *Solarize Plano Installation Metrics*

	US	TX	DFW	PLANO	SP 1	SP 1, % of total	SP 2	SP 2, % of total	SP 1 & 2	SP 1 & 2, % of total
# installations cumulative 2008-2014	570,400	8,796	1,817	190		11%		12%		23%
# installations 2013	145,700	2,110	429	44						
# Installations 2014	189,000	2,272	916	100	20	20%	22	22%	42	44%
% increase from 2013-14	30%	8%	114%	127%						

pounds or metric tons of carbon dioxide equivalents (CO_2e) per kWh from the USEPA's eGRID program[16], the pilot Solarize Plano systems will avoid an estimated 173,481.18 lbs. or 78.69 metric tons eCO2/year (USEPA, 2012).

Several additional positive outcomes grew from the pilot Solarize Plano program, including:

- a second Solarize Program (2014) resulting in the installation of 22 homeowner GPV systems, (mentioned above);
- the "Bring Solar Home" campaign currently run by Plano Solar Advocates;
- reduced soft costs leading to overall reduced installation costs being offered to by Axium solar to all customers;
- homeowner led Facebook page, called "Rooftop Solar in CoServ", dedicated to making CoServ more "solar friendly;" and
- substantial outreach by Solarize Plano organizers to increase awareness about GPV and lessons from the Solarize program (Table 22).

Table 23. *Community Educational Outreach by Solarize Plano Organizers*

# Event	# Attendees	Event Type
36	515	Elementary school solar car classes and races
53	1145	High school solar energy classes
80	2300	Solar presentations at various locations and events
169	3900	**TOTAL**

- *Source:* Personal communication, Solarize Plano project Organizer (May, 2016)

[16] The preeminent source of emissions data for the electric power sector, eGRID is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. The eGRID program tracks emissions from specific reporting power plants, and also creates emissions factors for regions based on these real numbers (eGRID). ERCOT (average) CO2e= 1.14 lbs./kWh; .00052 metric tons/kWh (USEPA, 2012).

4.6.2 Program Participant Perspectives and Experiences: What Worked

The group model clearly worked well in facilitating adoption for a group of individuals' who were largely poised to say "yes" to purchasing PV. This first wave of adopters exhibited many characteristics in line with "innovators" and "early adopters" from Rogers' DOI theory. This was a group of technically savvy, financially secure, educated individuals, engaged in their communities, who came to the project eager to install if they could justify it financially. This group required little "uncertainty reduction," which was sufficiently provided by several program elements: trusted and respected opinion leaders (volunteer organizers), change agents (City of Plano), and installers; distribution utility staff that exhibited personal integrity; the comfort of group decision making; and the general ease of a guided and shepherded process. In sum, the Solarize model, deployed in conjunction with significant financial incentives, endorsed by a City, and led by organized, knowledgeable people with personal experience with PV, gave enough of the technical and financial facts and logistical support to facilitate what was ultimately an easy decision for most of these pilot project adopters. The adopters represent a section of the population that is able and eager to install solar, but that would likely have been "still be watching the sun hit [their] roof[s] and not taking advantage of that resource," were it not for the Solarize Plano program.

The project also appears to have efficiently supported several others in realizing that PV was not right "at this time" for them, either due to site limitations or financial considerations. Specifically, by providing a realistic range for project costs, PV electricity production, and anticipated energy savings, along with defined project commitment timelines, the program facilitated efficient and appropriate "no" decisions for many participants.

4.6.3 Room for Improvement

There is clear room for improvement in order to facilitate adoption for the section of the population that is interested (versus eager) and able to install GPV, but who need “more” uncertainty reduction support. This segment of the population could be attributed to Rogers’ ‘later’ early adopters and early majority categories. It is clear that there several participants who “*really wanted to*” adopt were still “on the fence,” and needed more detailed information in order to make the decision. While understandable, the organizers reluctance to discuss specifics in regards to buyback rates and potential impact on payback period may have left some unnecessarily confused. In this case, there may have been participants able and willing to adopt but left “watching the sun hit [their] roof and not taking advantage of that resource,” because they needed more specific information and time to commit. Including more real world examples specific to the region, perhaps presented by residents living with GPV, could serve later waves of more careful adopters.

Opportunities for translating the lessons from the pilot Solarize Plano, including concepts influencing adoption, program achievements, and opportunities for improvement, to the DFW region will be discussed further in Chapter 5.

CHAPTER 5

REGIONAL LESSONS FROM THE PILOT SOLARIZE PLANO PROJECT

Over the past decade, grid-connected photovoltaic (GPV) systems have emerged as a significant power producing technology, globally. As this technology becomes financially accessible to a broader array of market segments, it has the potential to play an important role in strategies to reduce air pollution and greenhouse gas emissions, to decrease reliance on fossil fuels, increase reliability of the electric grid, and promote energy independence at a variety of scales. When installed on a home, a GPV system provides the additional benefit of offsetting a portion of the homeowner's electricity demand and costs for the life of the system. Residential GPV will likely serve a growing role in the evolving "smart" management of electricity.

Interest in GPV has grown in north Texas in recent years. State efficiency and renewable energy mandates have encouraged utilities to offer customer incentives for GPV, which when combined with falling hardware prices, have certainly contributed to an increase in regional installations. Various stakeholders have begun to recognize the value of GPV in reducing the impacts of a booming north Texas population on the already constrained electric grid and air shed. Non-government organizations such as the North Texas Renewable Energy Group (NTREG) and local industry have been working for years to promote awareness about GPV, and the recent involvement of the North Central Texas Council of Governments (NCTCOG) has brought a new level of coordination and resources to addressing market barriers.

Several notable outcomes have already emerged from the NCTCOG's Solar Ready II initiative, including: progress toward the stated goals of improving regional permitting procedures and reducing the associated soft cots, increasing networking and education about GPV in general, and the creation and implementation of the Solarize Plano project. NCTCOG and the member agencies continue to work to develop the regional GPV market. The literature has indicated that regional efforts to develop GPV will be more successful if grounded in an understanding of the local context, including not only the actual quantitative installation measures, but also the qualitative understanding of values, experiences, and perspectives of potential adopters and other stakeholders.

The goal of this study has been to contribute to this regional understanding by combining rich, qualitative "adopter-centered" research into factors influencing adoption, with quantitative analysis of regional trends as compared to those for the State and the U.S. The Solarize Plano project is used to better understand factors influencing adoption in the region, to evaluate the success of the model in overcoming barriers to GPV, and to identify lessons about adoption and the Solarize model that may be extrapolated to the region. Research objectives presented in Chapter 1 (p. 18) have been largely achieved. Achievements and limitations are discussed for each objective below, with recommendations for additional research and program development folded into discussion for each of the specific objectives.

5.1 Objective 1: Summarize baseline metrics and distribution for GPV adoption in the case study area and the region and compare to similar metrics for Texas and the U.S.

5.1.1. Achievements and Limitations of Knowledge

Using permit based datasets, a clear picture has been presented of regional installation numbers and locations over time for the study area as compared to trends for the State and the United States. Eleven “high-performing” cities in terms of total and relative adoption have been identified, including Plano. The average level of education, income, and percent of population “living in the same house as one year ago,” were found to relate to the number of installations in a community in a non-random way, with education level for the “high-performing” cities higher than that for the region.

Using the State of Texas average for residential system size allowed for a reasonable estimation of trends in local and regional installed capacity over time as compared to Texas and the U.S., but data for average pre-installed system costs were lacking for the region. It is clear that the lack of state-mandated public reporting of basic measures, including zip code level geographic identification at a minimum, limits trend analysis moving forward.

5.1.2. Regional Lessons and Recommendations

It is recommended that regional stakeholders advocate for State mandated public reporting of GPV system details, including size, pre-incentive installed costs and location (at least to zip code level). Alternatively, or additionally, it is recommended that standard and consistent data collection of the above items be promoted by the NCTCOG as a part of its work to streamline and standardize permitting in the region, and that a database be maintained for regional GPV permit records as supplied by member agencies.

5.2 Objective 2: Identify concepts important to GPV adoption from an end user perspective in the DFW area.

5.2.1 Achievements and Limitations of Knowledge

In depth interviews of Solarize Plano participants reveal several factors influencing adoption and highlight where these factors are shared and differ between program adopters and non-adopters. These concepts are considered the key findings of this dissertation and so will be summarized here. First, the most important factor identified by all program participants in their decision to adopt (or not) a GPV system, is whether or not the project is determined to make financial sense. Importantly, the process for evaluating the project's "financial sense" is found to vary notably between the groups. Most Solarize Plano adopters entered the project very close to committing to purchase, but were seeking to validate this decision, especially financially, to gain support in walking though the steps of the process from installer selection to installation logistics.

Adopters generally required only basic assurance that the project would pay for itself in energy savings over 9-10 years. With a trusted information source providing this validation, along with an efficiency process for making the purchase and installation, this group moved quickly to committing to purchase residential GPV. Non-adopters were hoping for a shorter payback period than is currently realistic and generally needed more extensive explanation of the cost figures, as well as more general assurance about the overall process from purchase and permitting through installation and use.

Many participants valued the environmental benefits of GPV, but would not have purchased without the finances making sense. Also, many were interested in energy independence and several did not install due to the lack of being able to “use their own” electricity in a power outage. Most participants were looking for some guidance through a seemingly complicated process, and to not have to go through the steps “alone.” Trusted information sources and the group experience contributed to the program’s success for most participants, and many expressed the desire to hear from more people who had installed GPV. These findings are consistent with the previous research on attitudes, values, and perceptions about residential solar, but reflect local values and considerations. These findings are specific to Solarize Plano participants (see below).

5.2.2. Regional Lessons and Recommendations

In depth interviews identify several interesting themes summarized above, many of which may translate to other communities seeking to promote GPV. These concepts, such as the desire expressed by homeowners to have guidance and support from a trustworthy source to explain the technology and cost considerations, and to walk them through the process, especially though selection of a contractor and buyback rate, can be tested for relevance in other communities with interview methods, or more efficiently with focus groups or surveys. The concepts presented in this research can provide a baseline or reference that can be refined for each community. One possibility is that a survey based on the concepts identified here be created for use in communities seeking to better understand barriers and priories among their homeowners.

It is further recommended that the adoption factors identified here, including socio-demographic variables, be studied in depth in the other ten high performing cities, with interview, focus group, or survey methods, and that findings be compared to those for the Solarize Plano case study.

5.3 Objective 3: Evaluate effectiveness of the Solarize Plano project in overcoming customer barriers to GPV adoption.

5.3.1. Achievements and Limitations of Knowledge

The in depth interviews of Solarize Plano participants also provide a clear picture of what worked for the pilot Solarize Plano project and what areas could be improved upon. As discussed, this program worked very well for the group of highly educated, technically savvy, financially secure people in the community that were almost ready to adopt when they entered the program. The group process facilitated by knowledgeable, organized individuals, worked well to answer the questions shared by this group and to facilitate the purchase process. The process also seemed to work well for those participants who were interested in solar electricity but who needed specifics on the financial analysis to see that their expectations would not be met.

Programmatic qualities were identified as important to Solarize Plano's success: being led by volunteers who were knowledgeable and experienced with GPV, who were highly dedicated and had the time to commit to the project's implementation; having the project be endorsed by the City; and having a good working relationship between program organizers, installers, and the utility. The interviews also identified important areas for improvement (see below) that may be useful for other communities in the region.

5.3.2. Regional Lessons and Recommendations

The Solarize Model could be effective in reducing barriers to GPV adoption in many other north central Texas communities. There are three key recommendations for applying findings from this study to other north Texas communities. First, it is likely that this model may have the same success, with very little modification, in other north Texas communicates with similar population characteristics as Plano, specifically: high levels of education and income among residents, and with a high percentage of residents employed in the high tech industry. Additional community-specific research as described in section 5.2.2. will contribute to program modifications that may better address unique or nuanced needs and concerns. Finally, it is likely that there are many homeowners in the region who, similar to some Solarize Plano non-adopters, may benefit from additional “help” understanding the financial evaluation. Expanding opportunities for those in the region living with GPV to share their experiences, especially details on costs, buyback rates, and other specifics, is highly recommended.

5.4. Concluding Objective: Identify lessons from the Solarize Plano project to formulate recommendations for increasing GPV in the DFW area.

The residential GPV market in DFW is growing, but is not yet developing in a consistent manner across the region. Several specific recommendations have been presented to support the development, implementation, and evaluation of effective regional policy and programming for GPV. Key summary recommendations include:

1) The region would benefit from a system for ongoing, consistent tracking of GPV installation metrics, which could be hosted and managed by the NCTCOG;
2) Many individuals in the region may be interested in adopting solar, and would likely benefit from independent, trustworthy guidance on the financial evaluation, technical specifics, and logistical processes involved in purchasing and installing GPV;
3) The Solarize Plano program offers one model for providing the above guidance for homeowners, and was successful in reducing barriers to GPV adoption in Plano;
4) Any model embodying the key programmatic characteristics of Solarize Plano identified above (in section 5.3.1) can serve to reduce adoption barriers among homeowners in the DFW region; and
5) The needs for each north Texas community will be best reflected by qualitative validation of the concepts presented in this research.

The concepts influencing GPV adoption among north Texas homeowners will certainly adjust overtime, as more people install systems. Hopefully regional collaboration will continue, and that partnerships between local government agencies, universities, community groups, and other researchers continue to develop and integrate processes for maintaining and sharing quantitative and qualitative tracking of adoption measures and project evaluation.

APPENDIX A

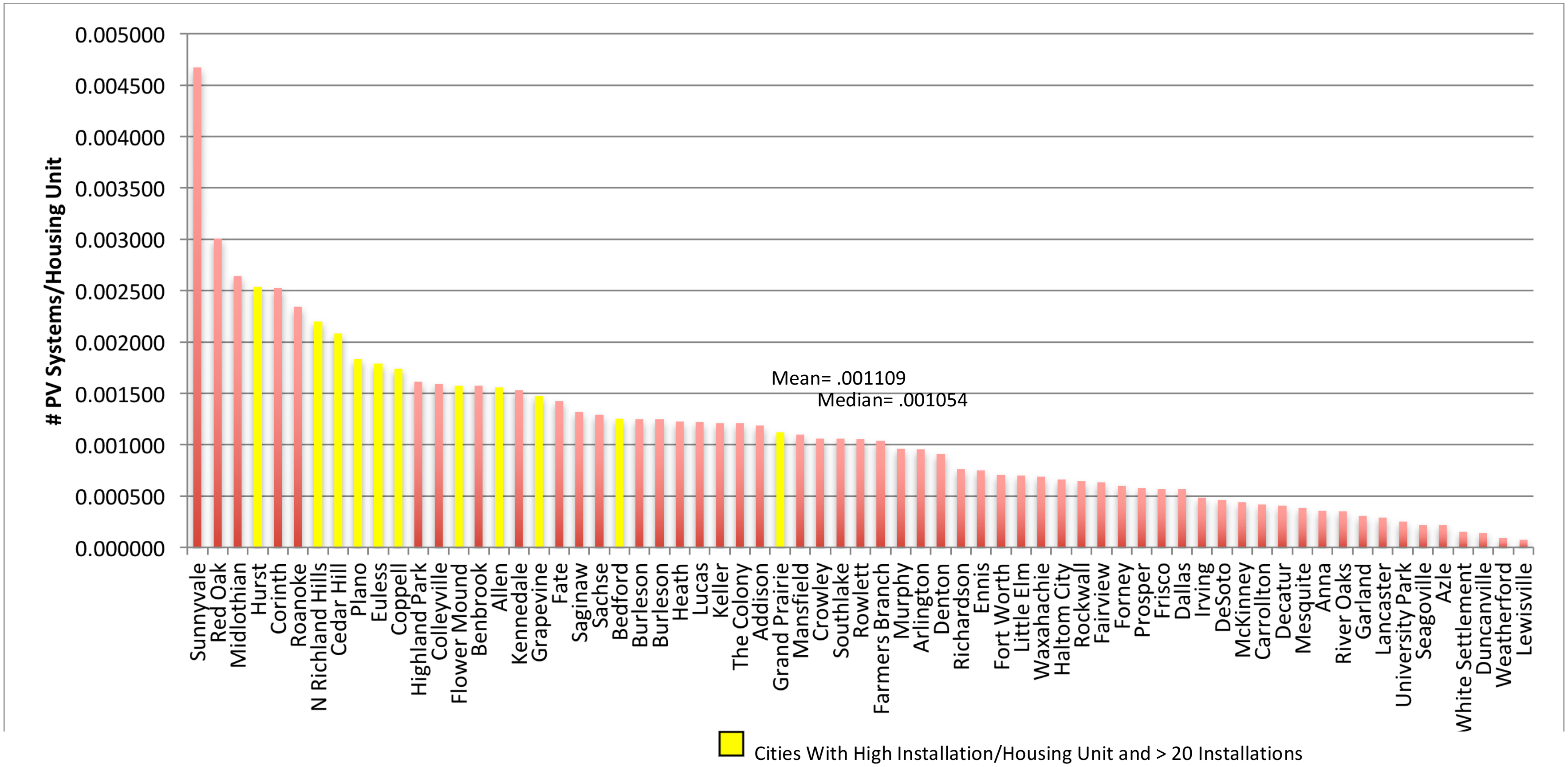
ADDITIONAL GPV METRICS

Installation Metrics for 82/169 NCTCOG Cities Reporting GPV Systems (Squyres, 2014; U.S. Census 2014a)

	City	Count	Percentage	Population
1	Dallas	293	15.93%	1,281,047
2	Fort Worth	205	11.15%	812,238
3	Plano	190	10.33%	278,480
4	Arlington	138	7.50%	383,204
5	Grand Prairie	70	3.81%	185,453
6	N Richland Hills	58	3.15%	68,529
7	Allen	45	2.45%	94,179
8	Irving	44	2.39%	232,406
9	Denton	42	2.28%	128,205
10	Euless	42	2.28%	53,630
11	Hurst	40	2.18%	38,733
12	Cedar Hill	34	1.85%	48,084
13	Flower Mound	34	1.85%	69,650
14	Richardson	31	1.69%	108,617
15	Grapevine	29	1.58%	50,844
16	Bedford	28	1.52%	48,908
17	Coppell	25	1.36%	40,678
18	Garland	25	1.36%	235,501
19	Frisco	24	1.31%	145,035
20	McKinney	21	1.14%	156,767
21	Mansfield	21	1.14%	62,246
22	Mesquite	20	1.09%	144,416
23	Rowlett	20	1.09%	58,407
24	Carrollton	19	1.03%	128,353
25	Corinth	18	0.98%	20,836
26	Burleson	17	0.92%	41,818
27	Keller	17	0.92%	43,924
28	The Colony	17	0.92%	41,352
29	Burleson	17	0.92%	41,818
30	Midlothian	17	0.92%	20,934
31	Benbrook	16	0.87%	22,419
32	Colleyville	13	0.71%	24,952
33	Farmers Branch	12	0.65%	32,560
34	Red Oak	12	0.65%	11,560
35	Haltom City	11	0.60%	43,913
36	Addison	10	0.54%	15,457
37	Rockwall	9	0.49%	41,785
38	Southlake	9	0.49%	29,086
39	Sachse	9	0.49%	23,681
40	DeSoto	9	0.49%	51,934
41	Saginaw	9	0.49%	21,703
42	Sunnyvale	8	0.44%	5,766

43	Waxahachie	8	0.44%	32,344
44	Roanoke	6	0.33%	6,974
45	Highland Park	6	0.33%	8,950
46	Little Elm	6	0.33%	35,414
47	Ennis	5	0.27%	18,823
48	Crowley	5	0.27%	14,572
49	Murphy	5	0.27%	20,230
50	Lancaster	4	0.22%	38,453
51	Haslet	4	0.22%	*1,517*
52	Justin	4	0.22%	3246
53	Kennedale	4	0.22%	7394
54	Krum	4	0.22%	4,632
55	Oak Point	4	0.22%	2786
56	Parker	4	0.22%	3811
57	Lewisville	3	0.16%	102,889
58	Fate	3	0.16%	8,812
59	Forney	3	0.16%	17,536
60	Heath	3	0.16%	7999
61	Lowry Crossing	3	0.16%	1711
62	Duncanville	2	0.11%	39,707
63	Fairview	2	0.11%	8,361
64	Hudson Oaks	2	0.11%	1865
65	Lucas	2	0.11%	6,554
66	Prosper	2	0.11%	14,416
67	University Park	2	0.11%	24,396
68	River Oaks	1	0.05%	7,671
69	Aledo	1	0.05%	2716
70	Anna	1	0.05%	10,571
71	Argyle	1	0.05%	3282
72	Azle	1	0.05%	11,530
73	Dalworthington Gardens	1	0.05%	2336
74	Decatur	1	0.05%	6,339
75	Ferris	1	0.05%	2436
76	Lake Worth	1	0.05%	4584
77	Lakeside	1	0.05%	1307
78	Rhome	1	0.05%	1067
79	Seagoville	1	0.05%	15,723
80	Weatherford	1	0.05%	27,769
81	Westworth Village	1	0.05%	2472
82	White Settlement	1	0.05%	16,896

DFW City GPV Installations/Housing Unit, 67 Cites Reporting Systems and with Population ≥ 5,000



Installation Metrics and Sociodemographic measures for 67/169 NCTCOG Cities with populations ≥5,000 and reporting GPV Systems (Squyres, 2014; U.S. Census Bureau, 2014a & 2014b)

	City	# PV	% DFW	Population	Housing Units	#/Housing Unit	Median Household Income	% with Bachelor's degree or higher	% In Same House as 1 year ago
1	Sunnyvale	8	0%	5,766	1,713	0.004670	$100,517	50%	95%
2	Red Oak	12	1%	11,560	3,987	0.003010	$67,132	22%	86%
3	Midlothian	17	1%	20,934	6,435	0.002642	$72,126	28%	83%
4	Hurst	40	2%	38,733	15,761	0.002538	$53,488	26%	84%
5	Corinth	18	1%	20,836	7,126	0.002526	$85,170	40%	86%
6	Roanoke	6	0%	6,974	2,560	0.002344	$61,010	34%	78%
7	N Richland Hills	58	3%	68,529	26,395	0.002197	$62,927	31%	84%
8	Cedar Hill	34	2%	48,084	16,338	0.002081	$67,913	30%	89%
9	Plano	190	10%	278,480	103,672	0.001833	$82,944	55%	87%
10	Euless	42	2%	53,630	23,447	0.001791	$54,619	32%	79%
11	Coppell	25	1%	40,678	14,343	0.001743	$111,325	63%	86%
12	Highland Park	6	0%	8,950	3,717	0.001614	$192,946	83%	86%
13	Colleyville	13	1%	24,952	8,165	0.001592	$151,169	65%	93%
14	Flower Mound	34	2%	69,650	21,570	0.001576	$121,549	58%	89%
15	Benbrook	16	1%	22,419	10,163	0.001574	$64,553	33%	87%
16	Allen	45	2%	94,179	28,877	0.001558	$102,120	53%	87%
17	Kennedale	4	0%	7,394	2,617	0.001528	$75,278	24%	88%
18	Grapevine	29	2%	50,844	19,685	0.001473	$75,931	46%	81%
19	Fate	3	0%	8,812	2,108	0.001423	$89,505	41%	92%
20	Saginaw	9	0%	21,703	6,820	0.001320	$74,521	20%	87%
21	Sachse	9	0%	23,681	6,972	0.001291	$91,543	32%	86%
22	Bedford	28	2%	48,908	22,301	0.001256	$60,373	35%	83%
23	Burleson	17	1%	41,818	13,591	0.001251	$69,088	24%	84%
24	Burleson	17	1%	41,818	13,591	0.001251	$69,088	24%	84%
25	Heath	3	0%	7,999	2,451	0.001224	$152,379	60%	93%
26	Lucas	2	0%	6,554	1,641	0.001219	$119,968	50%	87%
27	Keller	17	1%	43,924	14,051	0.001210	$114,266	57%	84%

28	The Colony	17	1%	41,352	14,052	0.001210	$71,425	33%	83%
29	Addison	10	1%	15,457	8,419	0.001188	$60,456	55%	61%
30	Grand Prairie	70	4%	185,453	62,424	0.001121	$55,336	23%	86%
31	Mansfield	21	1%	62,246	19,106	0.001099	$89,774	41%	89%
32	Crowley	5	0%	14,572	4,714	0.001061	$64,836	24%	83%
33	Southlake	9	0%	29,086	8,494	0.001060	$170,742	69%	91%
34	Rowlett	20	1%	58,407	18,969	0.001054	$83,442	31%	92%
35	Farmers Branch	12	1%	32,560	11,549	0.001039	$58,666	33%	82%
36	Murphy	5	0%	20,230	5,196	0.000962	$121,360	54%	97%
37	Arlington	138	8%	383,204	144,805	0.00095301	$53,055	29%	80%
38	Denton	42	2%	128,205	46,211	0.00090887	$48,518	38%	69%
39	Richardson	31	2%	108,617	40,630	0.00076298	$70,959	51%	82%
40	Ennis	5	0%	18,823	6,641	0.00075290	$43,634	13%	78%
41	Fort Worth	205	11%	812,238	291,086	0.00070426	$52,492	27%	82%
42	Little Elm	6	0%	35,414	8,581	0.00069922	$81,866	31%	87%
43	Waxahachie	8	0%	32,344	11,554	0.00069240	$53,336	24%	77%
44	Haltom City	11	1%	43,913	16,626	0.00066161	$43,792	12%	81%
45	Rockwall	9	0%	41,785	13,957	0.00064484	$86,627	38%	86%
46	Fairview	2	0%	8,361	3,140	0.00063694	$74,285	62%	91%
47	Forney	3	0%	17,536	4,985	0.00060181	$72,681	28%	90%
48	Prosper	2	0%	14,416	3,469	0.00057654	$111,641	45%	83%
49	Frisco	24	1%	145,035	42,306	0.00056730	$112,155	58%	85%
50	Dallas	293	16%	1,281,047	516,639	0.00056713	$43,359	30%	81%
51	Irving	44	2%	232,406	91,128	0.00048284	$50,942	34%	77%
52	DeSoto	9	0%	51,934	19,488	0.00046182	$56,911	29%	89%
53	McKinney	21	1%	156,767	47,915	0.00043828	$82,988	45%	84%
54	Carrollton	19	1%	128,353	45,508	0.00041751	$69,282	37%	85%
55	Decatur	1	0%	6,339	2,441	0.00040967	$48,831	23%	81%
56	Mesquite	20	1%	144,416	51,952	0.00038497	$49,837	18%	83%
57	Anna	1	0%	10,571	2,776	0.00036023	$63,556	26%	88%
58	River Oaks	1	0%	7,671	2,854	0.00035039	$42,622	11%	88%
59	Garland	25	1%	235,501	80,834	0.00030928	$51,997	22%	85%
60	Lancaster	4	0%	38,453	13,622	0.00029364	$49,590	18%	89%
61	University Park	2	0%	24,396	7,884	0.00025368	$176,836	83%	78%
62	Seagoville	1	0%	15,723	4,551	0.00021973	$43,713	11%	88%
63	Azle	1	0%	11,530	4,590	0.00021786	$54,171	20%	81%

64	White Settlement	1	0%	16,896	6,630	0.00015083	$39,747	10%	79%
65	Duncanville	2	0%	39,707	14,011	0.00014274	$55,100	26%	90%
66	Weatherford	1	0%	27,769	10,853	0.00009214	$52,532	26%	80%
67	Lewisville	3	0%	102,889	39,967	0.00007506	$58,559	31%	75%
	Mean		1%	$88,051	32,099	0.00110925	$77,837	36%	84%

APPENDIX B

INTERVIEW GUIDES

Sample Interview Guide Questions- Solarize Plano Study- INSTALLED

1. So tell me about when you first got interested in Solar Electricity?
2. Could you tell me about how you heard about Solarize Plano?
3. Walk me through the process of participating in Solarize Plano?
4. Could you talk about your decision to install solar electricity on your home?
5. Tell me about your experience with the installer selected.
6. Could you tell me about your experience with the local utility?
7. Tell me about your participation in rebates or tax incentives?
8. Do you know any other people who have installed solar energy systems?
9. How have friends and neighbors reacted to your system?
10. Could you tell me about living with the PV system?
11. If you knew someone interested in installing a PV system, what would you recommend make the overall process easier?
12. If you knew of others organizing a Solarize program, what would you recommend to improve the (?) overall process?

Sample Interview Guide Questions- Solarize Plano Study- DID NOT INSTALL

1. So tell me about when you first got interested in Solar Electricity?
2. Could you tell me about how you heard about Solarize Plano?
3. Walk me through the process of participating in Solarize Plano?
4. Could you talk about your decision about whether or not to install solar electricity on your home?
5. Could you tell me what would have had you install a PV system?
6. Tell me about your experience with the installer selected.
7. Could you tell me about your experience with the local utility?
8. Do you know any other people who have installed solar energy systems?
9. If you knew someone interested in installing a PV system, what would you recommend make the overall process easier?
10. If you knew of others organizing a Solarize program, what would you recommend to improve the (?) overall process?

Sample Interview Guide Questions- Solarize Plano Study- ORGANIZERS

1. So tell me about when you first got interested in Solar Electricity?
2. Do you have a PV system on your home?
3. Could you tell me about how you heard about the Solarize model?
    - What was it about the model that had you think it might be a good fit for Plano?
4. Walk me through the process of organizing Solarize Plano?
5. Tell me about your experience with the installer selected.
6. Could you tell me about your experience with Oncor?
7. Tell me about your experience with the participants?
8. Tell me about your experience with the City of Plano.
9. How do you think installing in Plano compares to the process in other North Texas Communities?
10. Do you think the Solarize Program improved the process of installing in Plano?
11. Do you think other North Texas Communities would benefit from this model?
12. If you knew of others organizing a Solarize program, what would you recommend to improve the (?) overall process?
13. Do you think you will continue this model in Plano?

Sample Interview Guide Questions- Solarize Plano Study- STAFF

1. So tell me about how you first heard about Solar Electricity?
2. When did you hear about solar electricity systems in the City of Plano?
3. About how many PV systems have been installed in Plano?
4. Could you tell me about how you heard about Solarize Plano?
5. Walk me through the process of working with Solarize Plano?
6. Tell me about your experience with the installer selected by Solarize Plano?
7. Could you tell me about your experience with the local utilities?
8. Could you tell me how the process of installing in Plano compares to the process in other North Texas Communities (best, worst, why?)?
9. Do you think the Solarize Program improved this process?
   - Would you like to see the Solarize model continue in Plano?
10. Do you think other North Texas Communities would benefit from this model?
11. If you knew of others organizing a Solarize program, what would you recommend to improve the (?) overall process?
12. If you knew someone interested in installing a PV system, what would you recommend make the overall process easier?

Sample Interview Guide Questions- Solarize Plano Study- INSTALLER

1. So tell me about how you got interested in installing Solar Electricity?
2. How long have you been installing PV?
3. Had you been installing in Plano prior to the Solarize Plano program? Other North Texas communities (how many and which most often)?
4. Could you tell me about how you heard about Solarize Plano?
5. Walk me through the process of participating with Solarize Plano?
6. Tell me about your experience with the Solarize organizers.
7. Tell me about your experience with the Solarize participants (prompts).
8. Could you tell me about your experience with Oncor?
9. Tell me about your experience with the City of Plano.
10. Could you tell me how the process of installing in Plano compares to the process in other North Texas Communities (best, worst, why?)?
11. Do you think the Solarize Program improved this process?
12. Do you think other North Texas Communities would benefit from this model?
13. If you knew of others organizing a Solarize program, what would you recommend to improve the (?) overall process?
14. Do you have a PV system at your home?

APPENDIX C

SOCIODEMOGRAPHIC QUESTIONAIRRE

SOCIODEMOGRAPHIC QUESTIONAIRRE- UNT RESEARCH

Date_________________

Name____

(First) (Middle) (Last)

Address____

____

Place of Birth____

(City) (State)

Age_____

Education

Highest grade completed: 0 1 2 3 4 5 6 7 8 9 10 11 12

College: 0 1 2 3 4

Graduate: Y/N Highest Degree______________________________

Employment Status

____1. Employed

____2. Self-Employed

____3. Unemployed/looking for a job

____4. Unemployed/not looking for a job

____5. Part-Time worker

____6. Other, please explain__________________________________

Occupation____ How long________ (years)

What kind of work does the main wage earner in your home do? If you are the main wage earner, put "same as above."
___________________________________How long employed (months or years)

Total Family Annual Income (before taxes)

1. < $10,000
2. $10,000- $20,000
3. $21,000- $30,000
4. $31,000- $40,000
5. $41,000- $50,000
6. $51,000- $60,000
7. $61,000- $70,000
8. $71,000- $80,000
9. >$80,000

Living Arrangement
____1. Alone.
____2. With spouse.
____3. With spouse and children. How many children?______
____4. With parents.
____5. With boyfriend/girlfriend.
____6. With relatives. Name relationship.________
____7. With non-relatives. Whom?________________________________
____8. Other. Explain.____

Marital Status
____1. Single/never married
____2. Married How long?____ (years)
____3. Married/remarried How long?____(years)
____4. Divorced HowLong?____(years)
____5. Other. Explain______

What Race do you identify With?
____1. White/ Anglo-American.
____2. Black/African-American.
____3. Hispanic
____4. Asian
____5. Other____________________
____6. Don't know
____7. N/A

PHOTOVOLTAIC SYSTEM INFORMATION

Date Installed:_________________

Size of system kWdc:_________________ or kWac: ________________

Rebates received: Y/N (circle one) From: ______________________(utility program)

Tax incentives: Y/N (circle one) for year:______________ =

$__________________

Installed Cost: ______________________- Rebate___________________=______________

Utility:_______________________

Installer:_______________________

APPENDIX D

SLIDES EXCERPTED FROM

SOLARIZE PLANO ONLINE ENROLLEE WORKSHOP

JULY 2013

(PLANO SOLAR ADVOCATES 2016)

Solar System Size Example Calculations

Example #	1	2	3
estimated annual energy usage (kWh)	10,000	15,000	20,000
SMALL			
target % of annual usage to be produced by PV solar	33%	33%	33%
calculated annual usage to be produced by PV solar (kWh)	3,300	4,950	6,600
estimated PV solar installed size to reach desired production (kW)	2.4	3.5	4.7
MEDIUM			
target % of annual usage to be produced by PV solar	50%	50%	50%
calculated annual usage to be produced by PV solar (kWh)	5,000	7,500	10,000
estimated PV solar installed size to reach desired production (kW)	3.6	5.4	7.1
LARGE			
target % of annual usage to be produced by PV solar	67%	67%	67%
calculated annual usage to be produced by PV solar (kWh)	6,700	10,050	13,400
estimated PV solar installed size to reach desired production (kW)	4.8	7.2	9.6
Assumption:			
annual production (kWh) per 1kW installed PV solar	1,400		
for south facing installation in North Texas			

PV Solar Size/Cost Example 1

- Key Assumptions:
    - If installed retail cost of $4.25/watt (example price per watt)
    - South facing exposure for solar panels (typical panel (3' x 5') is rated at about 240W dc)
    - In North Texas area, **1 kWdc-p** creates about **1,404 kWh** per year
    - Annual electricity usage is 10,000 kWh

- Then some example system size/production calculations would be:
    - 10 panels - approx 2.4kW PV solar, produce 3,360 kWh, approx 34% of your annual usage
    - 15 panels - approx 3.6kW PV solar, produce 5,040 kWh, approx 50% of your annual usage
    - 20 panels - approx 4.8kW PV solar, produce 6,720 kWh, approx 67% of your annual usage

- System Cost Calculations for LARGE system (20 panels):
    - 4800 Wdc-p (4.8kWdc-p) installed system at $4.25/W = $20,400
    - Less $1.25/W approx Oncor incentive for 2013, then = $1.25 x 4800 = $6,000
    - Apply 30% tax credit to total installed cost less incentive, $14,400 * .3 = $4,320
    - Net cost to customer = $20,400 - $6,000 - $4,320 = $10,080, or $2.10/Wdc-p

- Using 25 years lifetime , a 4.8kWdc-p system will produce:
    - **25** years x **6,720** kWh = **168,000 kWh**
    - Net installed system cost $10,080 divided by 168,000 kWh = **$0.06/kWh** (not including O&M or module degradation, which are really not significant to this cost calculation)
    - Already less than the $0.08-$0.13/kWh typical utility cost today
    - And then ***FREE***
- Note - PV solar systems produce electricity for a long time - 40 years or more

$20,400 Total Installed Cost -$6,000 utility incentive $14,400 sub-total price paid -$4,320 30% Federal ITC $10,080 net system cost

PV Solar Size/Cost Example 2

- Key Assumptions:
    - If installed retail cost of $3.25/watt (example price per watt)

- South facing exposure for solar panels (typical panel (3' x 5') is rated at about 240W dc)
- In North Texas area, **1 kWdc-p** creates about **1,404 kWh** per year
- Annual electricity usage is 10,000 kWh

- Then some example system size/production calculations would be:
  - 10 panels - approx 2.4kW PV solar, produce 3,360 kWh, approx 34% of your annual usage
  - 15 panels - approx 3.6kW PV solar, produce 5,040 kWh, approx 50% of your annual usage
  - 20 panels - approx 4.8kW PV solar, produce 6,720 kWh, approx 67% of your annual usage

- System Cost Calculations for LARGE system (20 panels):
  - 4800 Wdc-p (4.8kWdc-p) installed system at $3.25/W = $15,600
  - Less $1.25/W approx Oncor incentive for 2013, then = $1.25 x 4800 = $6,000
  - Apply 30% tax credit to total installed cost less incentive, $9,600 * .3 = $2,880
  - Net cost to customer = $15,600 - $6,000 - $2,880 = $6,720, or $1.40/Wdc-p

- Using 25 years lifetime, a 4.8kWdc-p system will produce:
  - **25** years x **6,720** kWh = **168,000 kWh**
  - Net installed system cost $6,720 divided by 168,000 kWh = **$0.04/kWh** (not including O&M or module degradation, which are really not significant to this cost calculation)
  - Already less than the $0.08-$0.13/kWh typical utility cost today
  - And then ***FREE***
- Note - PV solar systems produce electricity for a long time - 40 years or more

$15,600 Total Installed Cost -$6,000 utility incentive $9,600 sub-total price paid -$2,880 30% Federal ITC $6,720 net system cost.

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