Microgeneration Technology Performance in the Irish Housing Stock

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Overview

- Introduction
- Solar water heating systems
- Grid-connected PV systems
- Behavioural studies
- Policy analysis
- Conclusions

Introduction

- The aim of the four-year inter-disciplinary study was to identify which domestic-scale, retrofit microgeneration technologies are most economically viable in the Irish housing stock and should be favoured by policy makers in the medium to long term (10-30) years.

- The technologies which were considered in the study are: solar thermal water heating systems; grid-connected photovoltaic systems; wood pellet boilers; ground source heat pumps; micro wind turbines; and micro-CHP.

- Solar results are the focus of this presentation.

Introduction

The objectives of the project were to address the following questions:

- what technologies will become economically attractive to individual investors over the period and what subsidies are required to make them viable?
- what are the household characteristics which favour microgeneration uptake?
- what would be the associated cost to the exchequer for each technology, does this represent value for money and which technologies should be most favoured?
- what are the main non-economic barriers to the uptake of microgeneration technologies?
- which economic and non-economic policies would facilitate the uptake of the most favoured technologies?

Introduction

The methodological approach comprised three main areas:

- modelling the investment viability of technologies at an individual building level using transient net energy balance models which combine demand and microgeneration supply data;

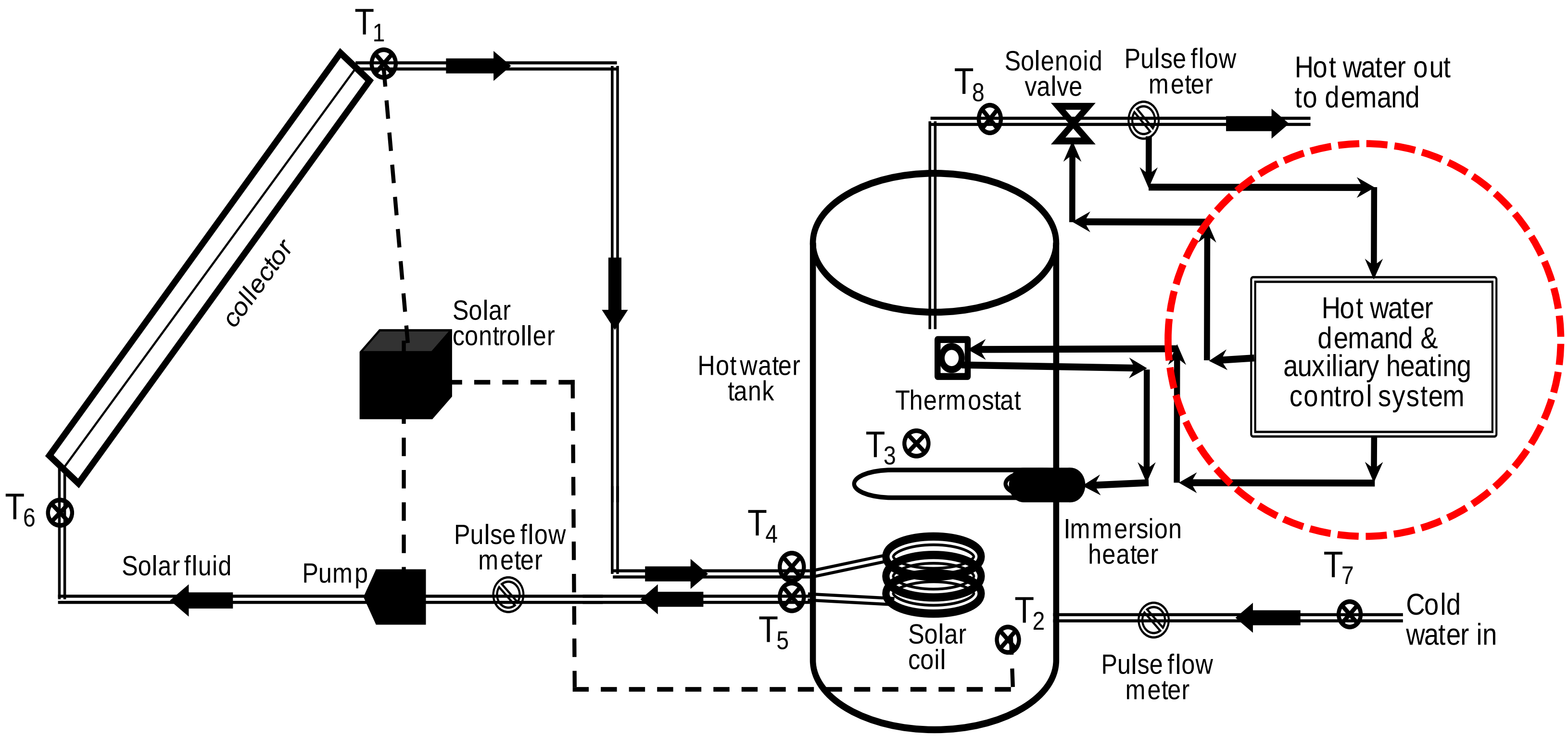
- assessing the non-economic barriers to the uptake of microgeneration technologies using a national market survey; and

- aggregating the above economic and non-economic data to establish technology deployment potential, cost to the exchequer and cost of carbon abated under a number of different future policy scenarios.

SOLAR WATER HEATING SYSTEMS

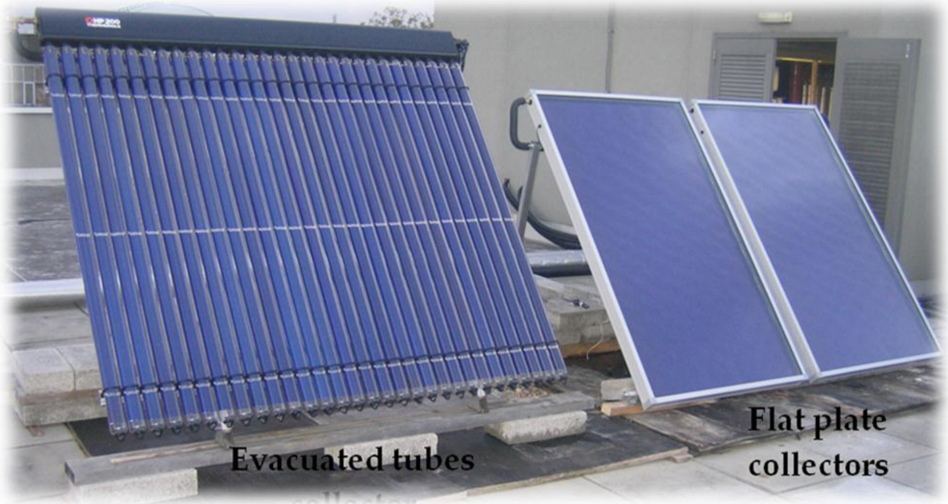
System design

- Forced circulation
- 300 litres stainless steel tank
- 3 m^2 heat pipe evacuated tube (30 tubes) or 4 m^2 flat plate collectors
- Control sub-system that dispensed hot water demand profile and controled auxiliary heating cycle



Conceptual design of the solar water heating systems

Field trial installations



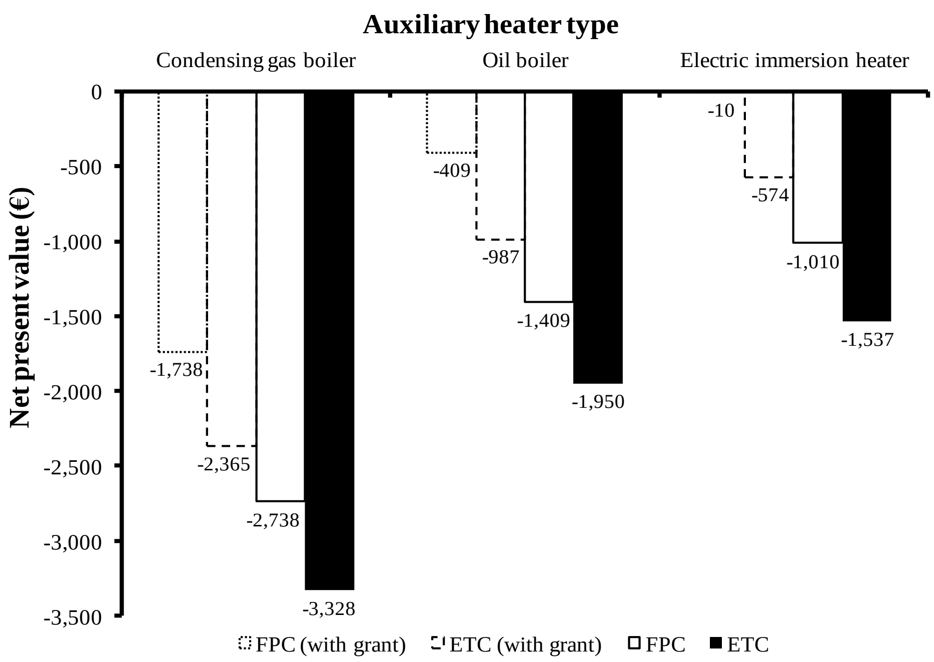
Energy performance

Comparative field performance

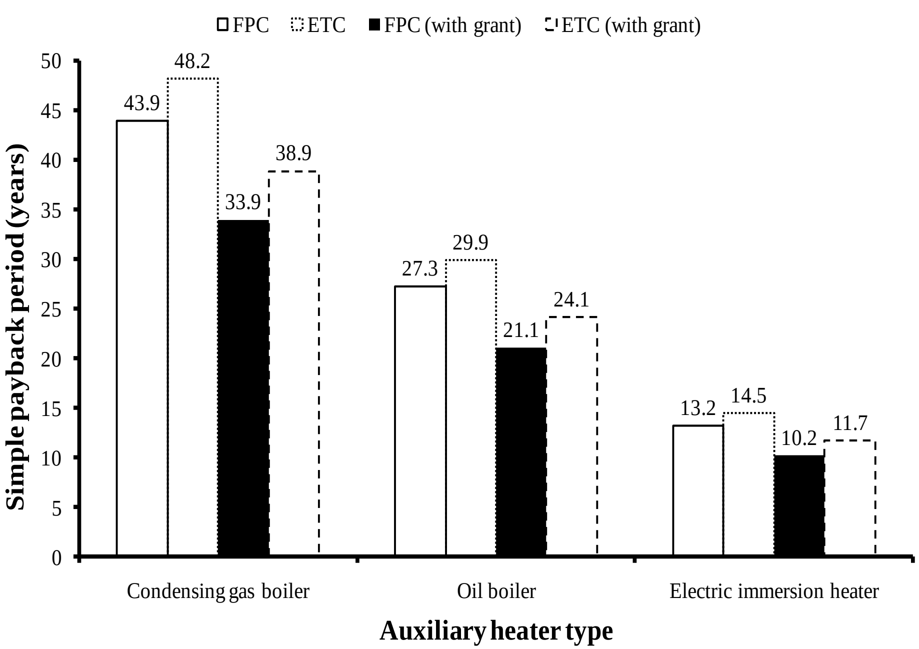
Item description	**FPC (4 m^2)**	**HP-ETC (3 m^2)**
In-plane solar insolation (kWh/m^2/d)	1,087	1,087
Energy collected (kWh/yr)	1,984	2,056
Energy delivered (kWh/yr)	1,639	1,699
Energy collected per unit area (kWh/m^2/yr)	496	681
Supply pipe losses (kWh/yr) (15 m)	326 (16.4%)	366 (17.8%)
Solar fraction (%)	38.6	40.2
Collector efficiency (%)	46.1	60.7
System efficiency (%)	37.9	50.3

L.M. Ayompe, A. Duffy, M. Mc Keever, M. Conlon and S.J. McCormack. Comparative field performance study of flat plate and heat pipe evacuated tube collectors for domestic water heating systems in a temperate climate. *Energy* (2011): 36; 5, 3370-3378.

Economic performance



NPVs for SWHSs with different auxiliary heaters in 2010



SPP for SWHS with different auxiliary heaters in 2010

L.M. Ayompe, A. Duffy, M. Mc Keever, M. Conlon and S.J. McCormack. Comparative field performance study of flat plate and heat pipe evacuated tube collectors for domestic water heating systems in a temperate climate. *Energy* (2011): 36; 5, 3370-3378.

GRID-CONNECTED PHOTOVOLTAIC (PV) SYSTEM

Field trial Installation

PV module/array	Specification
Type	Monocrystalline silicon
Cell efficiency	19.3%
Module efficiency	17.2%
Maximum power (P_{max})	215 W
Maximum power voltage (V_{pm})	42.0 V
Maximum power current (I_{pm})	5.13A
Open circuit voltage (V_{oc})	51.6 V
Short circuit current (I_{sc})	5.61 A
Warranted minimum power (P_{min})	204.3 W
Output power tolerance	+10/-5 %
Maximum system voltage (V_{dc})	1000
Temperature coefficient of P_{max}	-0.3 %/^{o}C
Module area	1.25m^2
No. of modules	8
NOCT	47±2^{o}C

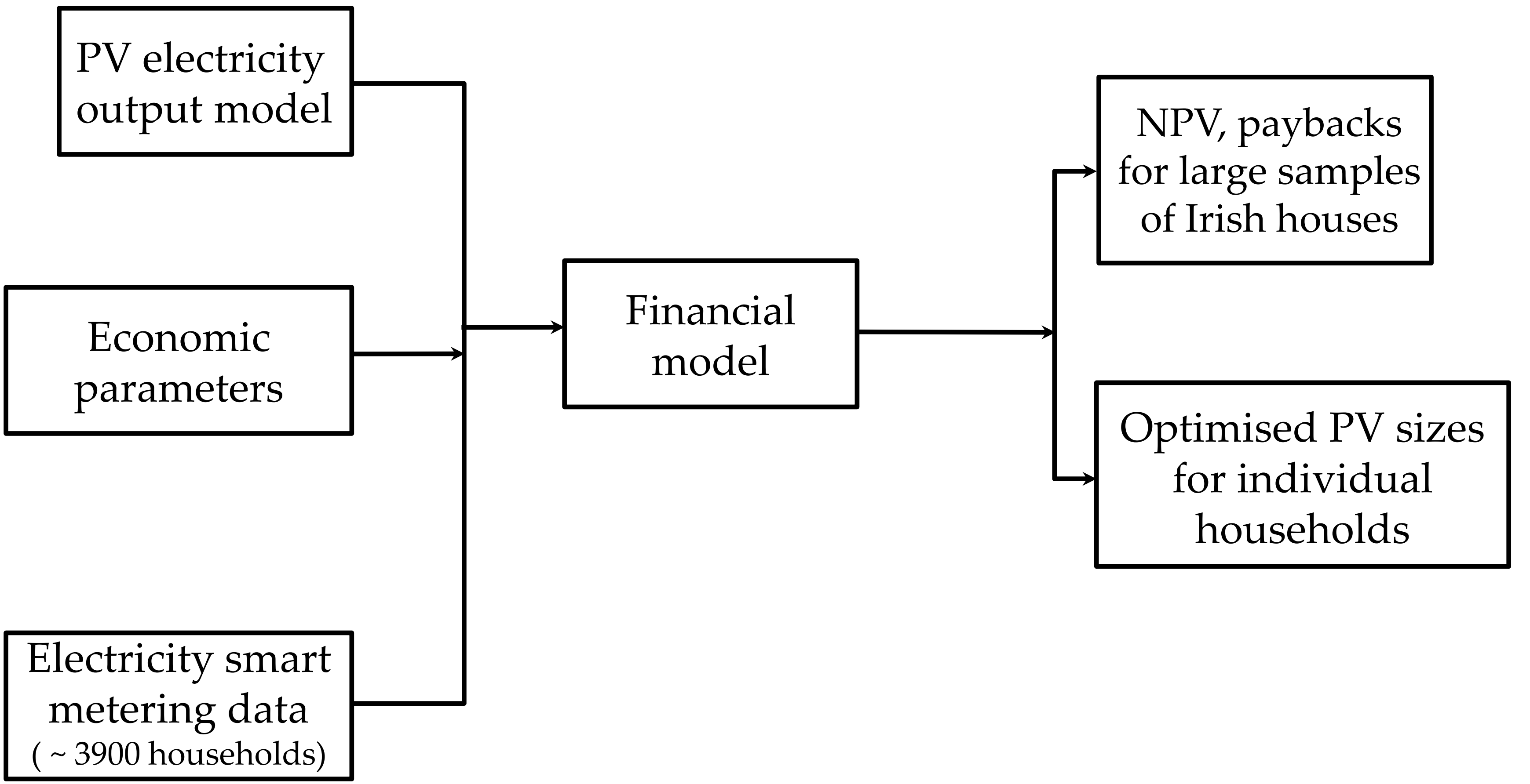
Field performance – International comparison

Location	PV type	Energy output (kWh/kW_p)	Final yield (kWh/kW_p-day)	PV module efficiency (%)	System efficiency (%)	Inverter efficiency (%)	Performance ratio (%)	Reference
Crete, Greece	PC-Si	1336.4	2.0-5.1	-	-	-	67.4	[8]
Germany		680	1.9	-	-	-	66.5	[13]
Málaga, Spain		1339	3.7	8.8-10.3	6.1-8.0	85-88	64.5	[21]
Jaén, Spain		892.1	2.4	8.9	7.8	88.1	62.7	[22]
Algeria	MC-Si			10.1	9.3	80.7	-	[23]
Calabria, Italy	PC-Si	1230	3.4	7.6	-	84.8	-	[24]
Germany		700-1000	1.9-2.7	-	-	-	-	[15]
Ballymena, Northern Ireland	MC-Si	616.9	1.7	7.5-10.0	6.0-9.0	87	60-62	[10]
Warsaw, Poland	A-Si	830	2.3	4.5-5.5	4.0-5.0	92-93	60-80	[25]
Castile & Leon, Spain	MC-Si	1180	1.4-4.8	13.7	12.2	89.5	69.8	[26]
Umbertide, Italy	PC-Si	-	-	4.0-7.0	6.2-6.7	-	-	[27]
UK		744	-	-	-	-	69	[9]
Liverpool, UK	Tiles	777	-	-	-	-	72	[9]
Dublin, Ireland	**MC-Si**	**885.1**	**2.4**	**14.9**	**12.6**	**89.2**	**72.4**	**Present study**
UK	A-Si	-	-	3.7	3.2	64.5	42.0	[10]
UK	PC-Si	-	-	-	7.5	-	68.0	[10]
UK	-	-	-	-	8.4	90-91	59-61	[10]
Italy	A-Si	-	-	-	-	-	66	[10]
Germany	-	-	-	-	-	-	50-81	[10]
Brazil	A-Si	-	-	-	5	91	-	[10]
Thailand	-	-	2.9-4.0	-	-	92-98	70-90	[28]

PC-Si: poly-crystalline silicon, MC-Si: mono-crystalline silicon, A-Si: amorphous silicon

L.M. Ayompe, A. Duffy, S.J. McCormack and M. Conlon. Measured performance of a 1.72 kilowatt rooftop grid connected photovoltaic system in Ireland. *Energy Conversion and Management* (2011): 52; 2, 816-825.

PV Financial Model



PV FIT design for Ireland

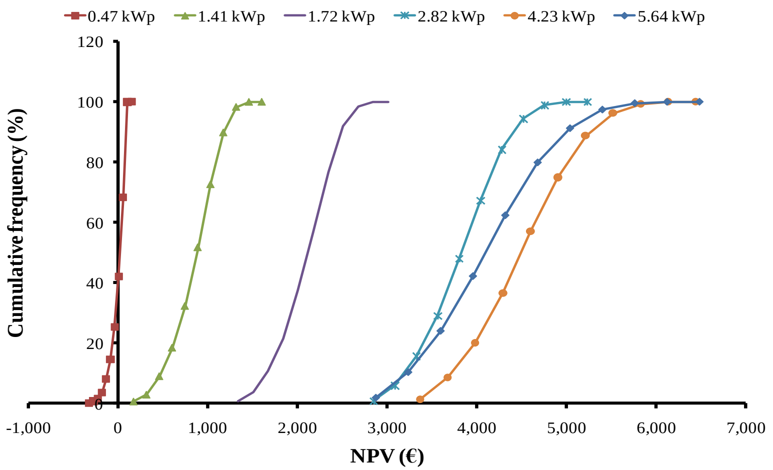
$$NPV = R_t - C_t$$

$$R_t = \sum_{n=1}^{n=N} \left(\alpha_n AI + \beta TG + \gamma_n EX \right)$$

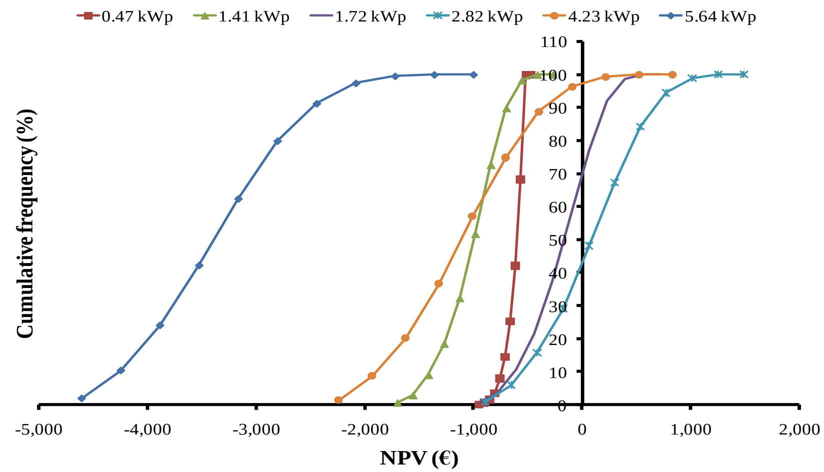
$$C_t = C_{mt} + C_{BOS} + C_{BOSrep} + C_v$$

NPV =	net present value (€)
C_t =	total life cycle cost (€)
R_t =	total revenue (€)
AI =	avoided import as a fraction of total electricity generated (kWh)
EX =	electricity export as a fraction of total electricity generated (kWh)
TG =	total generation (kWh)
α_n =	electricity import tariff in year "n" (€/kWh)
β =	generation based reward or FIT (€/kWh)
γ_n =	electricity export tariff in year "n" (€/kWh)
N =	PV system useful life (years)
C_{mt}	present value of cost associated with PV module (€)
C_{BOS}	present value of cost associated with the initial investment on BOS (€)
C_{BOSrep}	present value of BOS replacement cost (€)
C_v	present value of total variable cost (€)

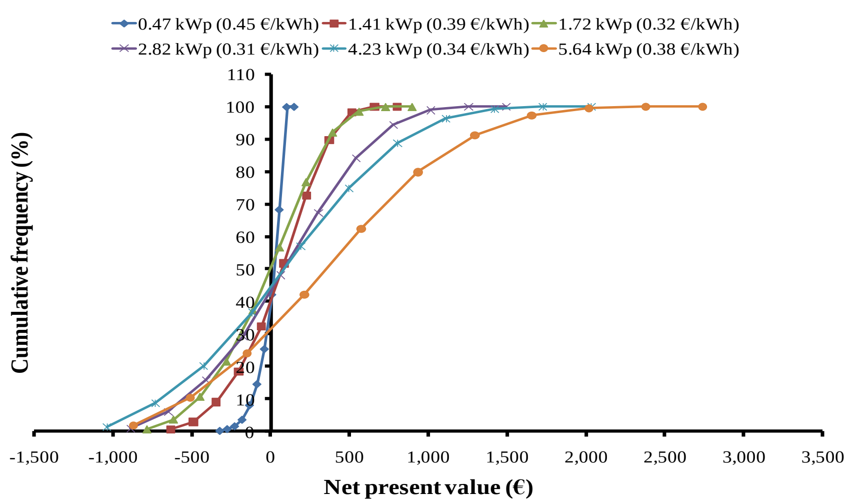
PV FIT design for Ireland



Cumulative frequency of NPVs for different PV system capacities in 2011 (0.45 €/kWh FIT)

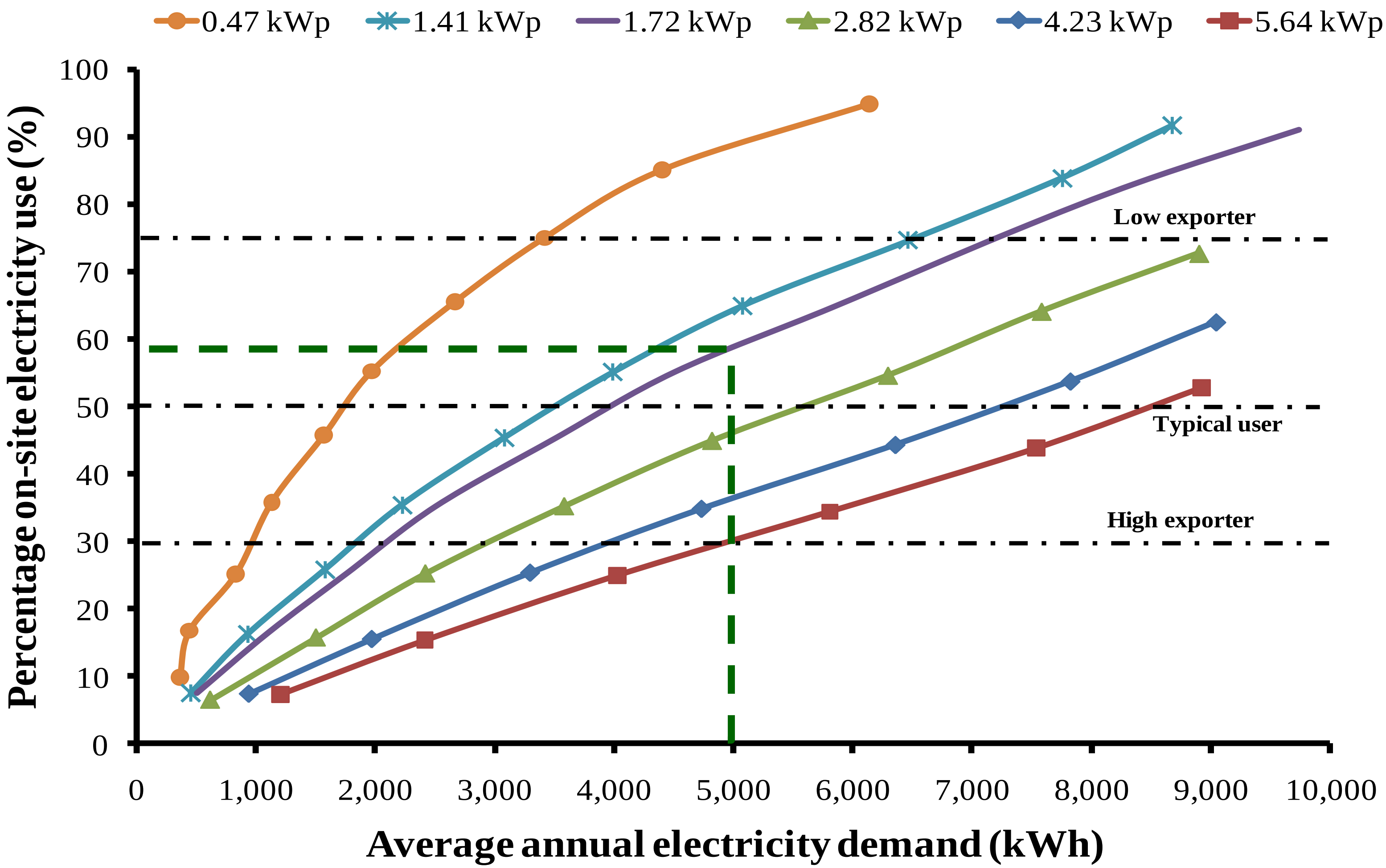


Cumulative frequency of NPVs for different PV system capacities in 2011 (0.31 €/kWh FIT)



Cumulative frequency of NPV for different PV system sizes and recommended FIT to achieve 8% IRR and at least 50% market penetration

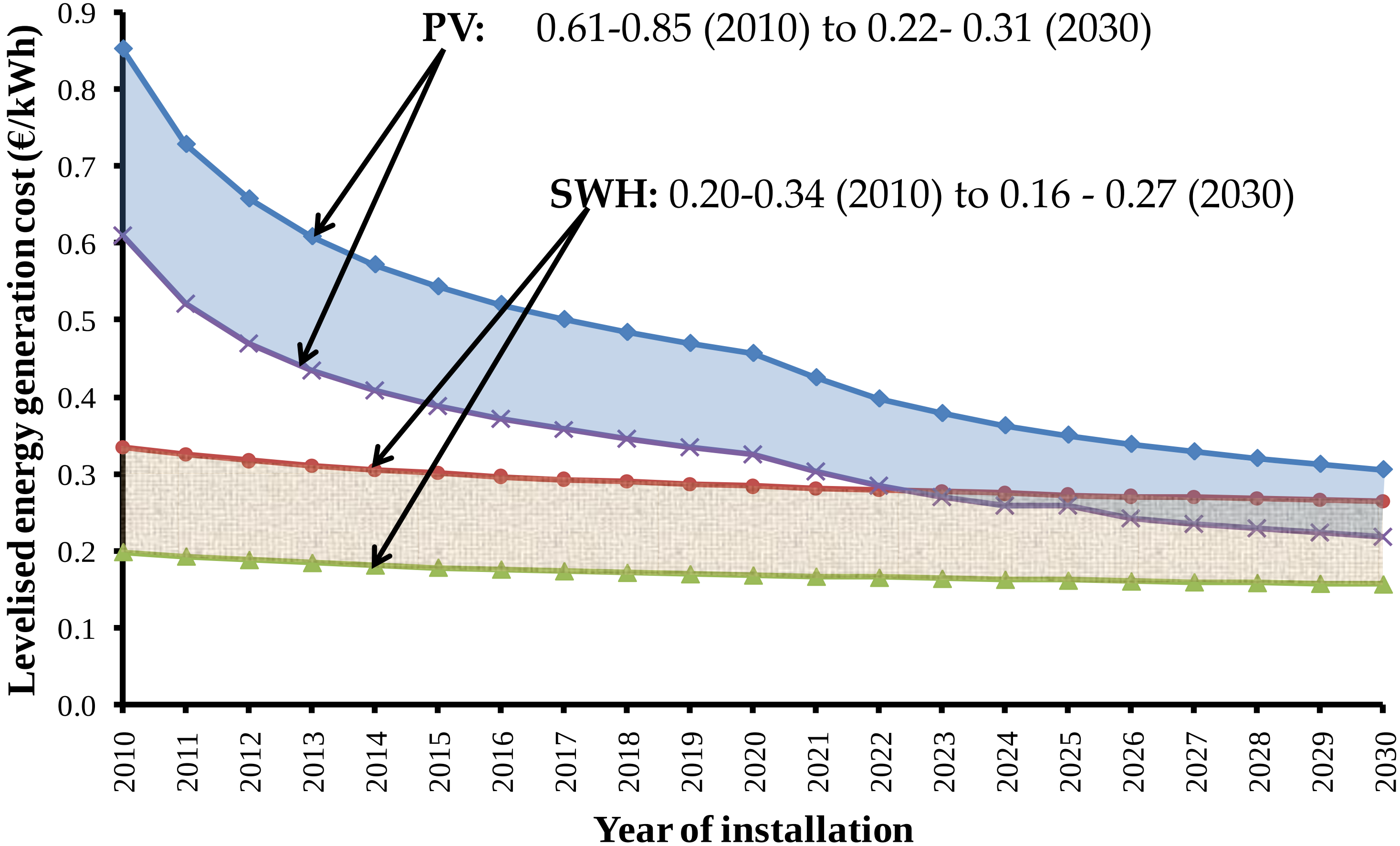
PV design chart



Percentage on-site household electricity use against average annual electricity demand

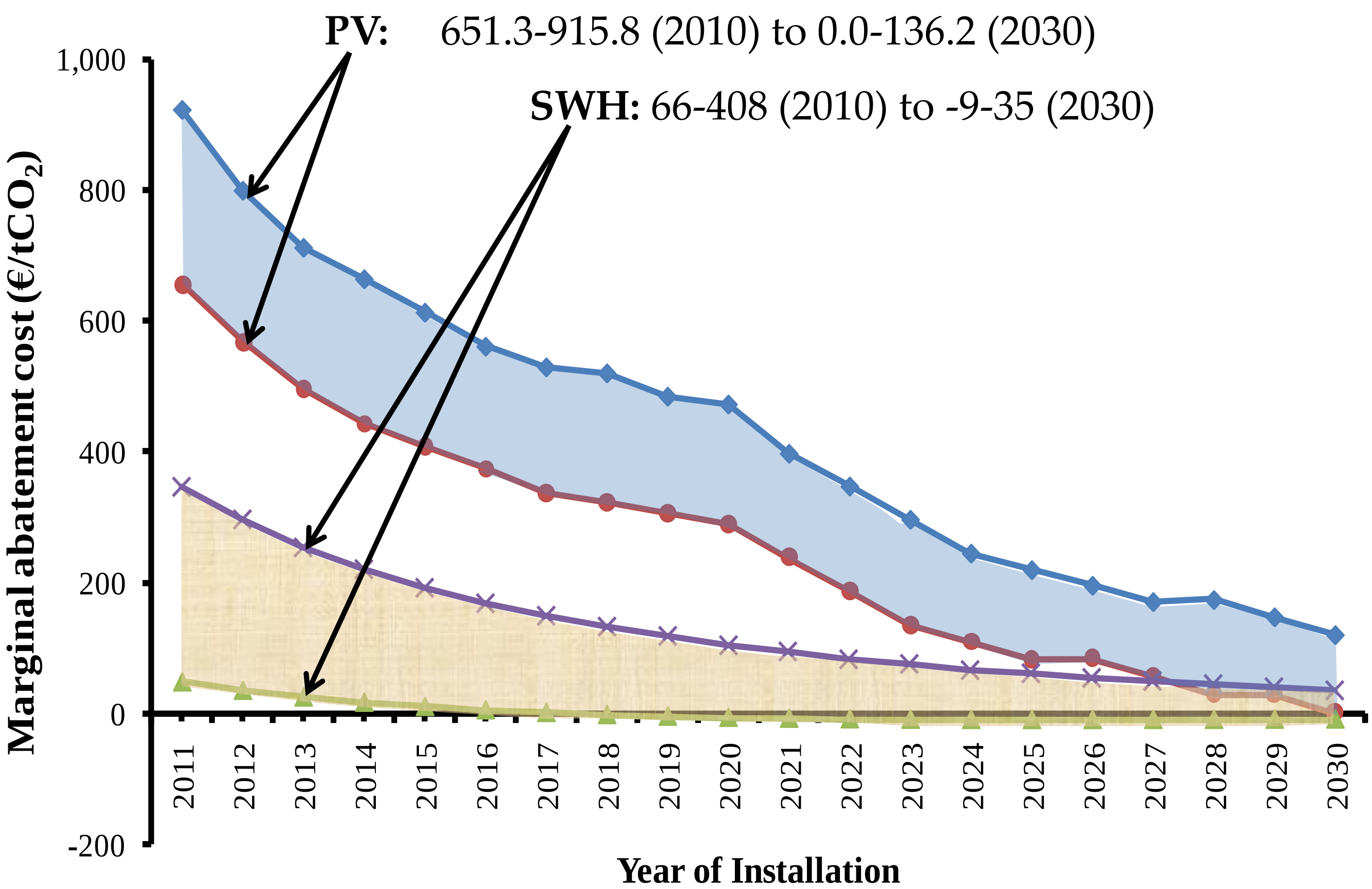
POLICY ANALYSIS

Levelised energy generation cost



Levelised energy generation costs for domestic scale PV and SWHSs between 2010 and 2030

Marginal abatement cost



Marginal abatement costs for domestic scale solar water heating systems and grid connected PV systems (2011 to 2030)

BEHAVIOURAL STUDIES

Active Resistance

- Sample size = 1010
- Computer Assisted Telephone Interviews administered by professional market-research company.
- Consumers willing to purchase within 12 months (~ 8%)
- Consumers' postponing decision (~ 42%)
  - Positive attitudes, perceive high relative advantage
  - Motives: high cost, functional risk, low social pressure
- Consumers' rejecting adoption (~ 50%)
  - Motives: low relative advantage, incompatibility with habits and values, functional risk, no social pressure

(Claudy et al.)

Awareness and Willingness to pay

Technology	Cost (€)		Payback period (years)		Awareness (%)*	
	Actual+	Median willingness to pay*	Actual	Average accepted*	Aware	Not aware
PV system	9,500 – 14,500	4,254	> 25	8.5	80	20
Solar water heating system	4,400 - 5,000	2,591	10.2 - 48	13	75	25

+ Typical prices

- Men higher awareness
- Younger and older people have a lower awareness
- People with internet access have higher level of awareness of microgeneration technologies.
- People in rural areas more aware
- No significant differences between social classes or household sizes

*M.C. Claudy, C. Michelsen, A. O'Driscoll, M.R. Mullen. Consumer awareness in the adoption of microgeneration technologies An empirical investigation in the Republic of Ireland. *Renewable and Sustainable Energy Reviews* (2010): 14; 2154-2160.

Conclusions

- There exists a wide range of performances for solar technologies for domestic application
- Policy makers have to be careful in designing support policies
- Both SWHS and grid-connected PV systems not yet economically viable
- Both technologies would however become viable in the future if global support policies are sustained
- FPC generated 496 kWh/m^2/yr
- HP-ETC generated 681 kWh/m^2/yr
- Level of subsidies for SWHSs
  - 1,000 to 2,750 for 4 m^2 FPC
  - 1,500 to 3,300 for 3 m^2 HP-ETC

Conclusion

- PV system generated 885 kWh/kW_p
- Parity between PV generated electricity and grid and wholesale electricity prices occurs soonest in 2020 and 2025
- New FIT design required since current tariff not suitable
- Required FITs range between 31-45 euro cents/kWh
- Single FIT not suitable for domestic scale PV systems
- MAC for ST is significantly lower that for PV until 2030
- More sensible to subsidize ST at present because it has a closer payback period

Thank you!

Any Questions?