WILLINGNESS-TO-PAY FOR OFF-GRID ELECTRICITY

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WILLINGNESS-TO-PAY (WTP) FOR ELECTRICITY

- **DEFINITION:** Willingness-to-pay (WTP) is the maximum amount that an individual is willing to pay for a good or service, in this case for electricity services. It depends on a variety of factors such as income levels, electricity prices, electrification level, availability of alternatives, value provided to the service, budget for electricity expenditure, amongst others (TERI, 2017).

- **PROBLEM:** WTP is a determinant factor for establishing electricity access and microgrids; however, it is currently poorly understood, both in theoretical and in practical terms. In developed countries, electricity access is not a critical issue, however WTP may become relevant to switch from grid-connection to off-grid electricity systems or local microgrids – either in line with a low-carbon energy system or with a more decentralized and independent system.

- **AIM:** With this project, we aim to increase our understanding of the WTP for off-grid electricity to be able to estimate how many people are willing to satisfy their electricity consumption either through grid-connection or microgrids.

- **METHODOLOGY:** A literature review has been carried out from empirical research on WTP studies on the field of electricity in both developing and developed countries to derive insights of alternative and improved ways to express the WTP and its applicability in grid-connection versus off-grid research, either for access to electricity in developing countries or microgrids in developed regions.

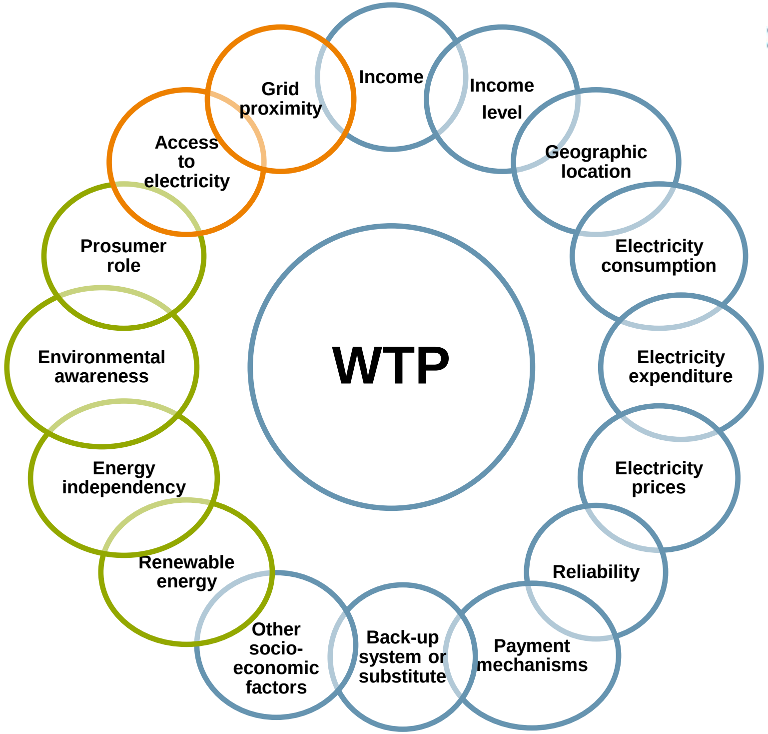
- **STRUCTURE:** The study starts with an overview of the main factors influencing WTP for electricity and estimation methods of WTP backed-up with case studies in developing and developed countries, covering survey-based methods (i.e. stated- and revealed-preference methods) and alternative analytical methods (i.e. regional and aggregated approach). This is followed by data insights of applicability in NL and grid-connection versus off-grid research. It is then finalized with conclusions and recommendations for further research.

MAIN FACTORS INFLUENCING WTP FOR ELECTRICITY

All countries

Developed countries

Developing countries



- Each factor can be expressed in different ways:
  - Income → GDP or total expenditure per capita or per household
  - Income levels → quintiles based on income distribution
  - Geographical location → rural and urban areas
  - Electricity expenditure → % of GDP or income or total expenditure
  - … (see Appendix A)

SURVEY-BASED METHODS

- Most widely used methods for WTP studies on the field of electricity → Contingent Valuation (CV) & Choice Experiments (CE) based on constructed hypothetical scenarios.
- In developed countries, WTP studies mainly focus on an increase of the provision of renewable energy options.
- Main WTP drivers → Environmental awareness, internalization of air pollution costs, income and electricity consumption.
- KEY POINTS → Differences in urban vs rural, payment mechanisms and preferences for wind power.

Australia (CV)
- WTP for an increase in electricity generation from renewable sources = $28 per quarter (average)

China (CV)
- WTP for renewable electricity = $28 per quarter (average)
- Mandatory mechanism

England (CE)
- WTP a higher price for a renewable energy program to internalize costs for energy security, climate change and air pollution

Finland (CE)
- WTP for energy from wood = €261 per year

Germany (CE)
- WTP for a more environmentally friendly electricity mix (16% renewables)

Greece (CV)
- WTP for an expansion of 10% of renewables in the electricity mix =€26.5 per quarter

Italy (CV)
- WTP for renewable energy = €4.62-8.05 per 2 months (median)

Japan (CV)
- WTP for renewable energy = US$17 per month (median)

Norway (CE)
- WTP between imports of electricity from coal-fired power plants vs building more hydro power, wind farms or gas-fired plants = wind power was preferred

Scotland (CE)
- WTP for renewable energy projects with no increase in air pollution = £14.40 per year

Spain (CV)
- WTP for a green electricity program = £14.40 per year

U.S. (CV / CE)
- WTP for 10% share of renewable energy = $14/ per month
- Collective mechanism and private provision
- WTP for decreased air emissions and 25% hydro power supply

SURVEY-BASED METHODS

- Other WTP studies in developed countries have focused on the value of reliability and residential outage costs. Conjoint Analysis (CA) has been used in studies to value outage costs and it is based on ranking possible outcomes (Baarsma and Hop, 2009).
- Main WTP drivers → income, frequency of power outages, duration, scheduling, time of the day (off-peak) and season (summer).
- KEY POINTS → Willingness to trade reliability for lower electricity bills.

- Although reliability is high in developed countries, the introduction of intermittent energy sources to the grid in the future might increase unreliability of supply.
- ↑WTP for renewable energy and ↓WTP for reliability

Australia (CE)	Belgium (CE)	Hong Kong (CV)	The Netherlands (CA)	Sweden (CE)
• WTP of $43 (on average) to avoid a one-time, two-hour power outage. • Customers value fewer and shorter outages.	• WTP for increased reliability = 75% negative, 9% positive, rest did not know. • Significant share is willing to switch to lower reliability for electricity bill discount (outages are rare <2 every 2 years).	• More than half of respondents would trade some reliability for a lower electricity bill.	• Households prefer short outages and a compensating discount on electricity bill. • The social cost of present reliability (30min/year with no electricity) is €2.80 per household (on average).	• WTP increases with the outages duration, during weekends and winter. • WTP has a positive relationship to income due to more electrical appliances.

ANALYTICAL METHODS
REGIONAL APPROACH

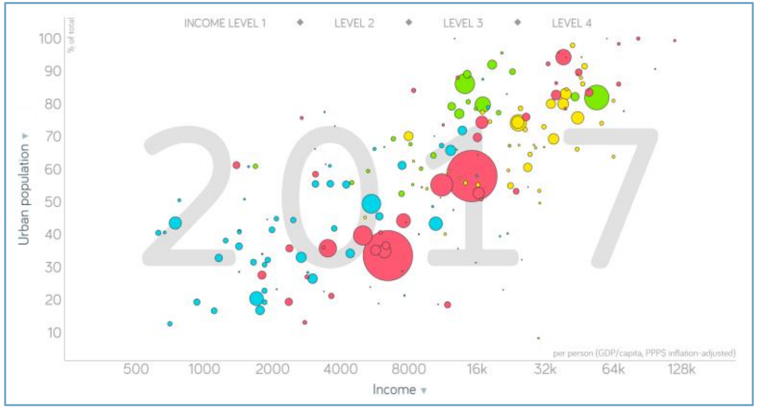
- A regional approach would take into account WTP differences in urban and rural regions, cities or leading or lagging areas.

- BASED ON URBAN VS RURAL – Empirical studies show that WTP has a positive relationship with income and that there is a positive relationship between the increase of urban share and GDP per capita, see figure 1 (Spence et al., 2009; Brooks, 2010). Artz et al. (2016) found that the average urban wage advantage is 38% and that for every 10% increase in GDP per capita, the urban-rural wage gap falls by 0.3%. Similarly, according to Young (2013), the urban-rural gap accounts for 40% of mean country inequality. In high-income countries, urban areas generate 85% of GDP (Young, 2013). Within the EU-27, most urban regions accounted for ~54.3% of GDP (Eurostat, 2013).

- BASED ON CITIES – Liddle (2013) found that most cities have a higher GDP per capita than their respective countries. Additionally, the cost of delivering basic services is 30-50% cheaper in concentrated population centers (McKinsey, 2011). The MGI Cityscope database holds socio-economic data per city and identification of clusters around the world.

- BASED ON LEADING AND LAGGING AREAS – The World Development Report (2009) specifies welfare measures for each area as % of each country's average welfare measure.

Figure 1: URBAN SHARE VS GDP PER CAPITA (PPP)



Source: World Bank and UN Population Division

WTP URBAN & RURAL HOUSEHOLDS (HH)

$$WTP_{Urban\ HH} = \%elect.expenditure\ x\ \frac{Nr.Urban\ HH\ x\ Income_{Urban\ HH}}{Electricity\ consumption_{Urban\ HH}}$$

$$WTP_{Rural\ HH} = \%elect.expenditure\ x\ \frac{Nr.Rural\ HH\ x\ Income_{Rural\ HH}}{Electricity\ consumption_{Rural\ HH}}$$

ANALYTICAL METHODS
AGGREGATED APPROACH

- An aggregated approach would incorporate differences in income levels, electricity expenditures and electricity consumption.

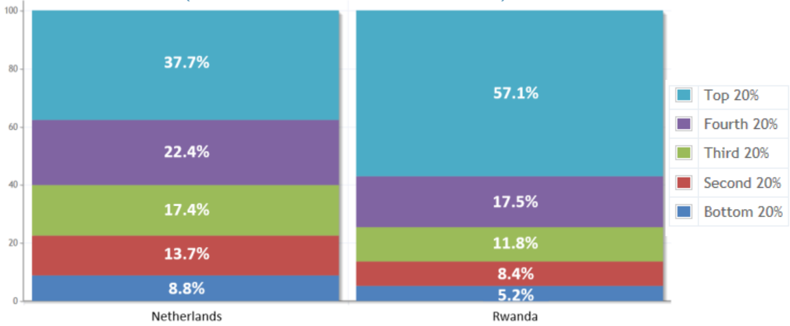
- INCOME LEVELS – The distribution of income varies per country based on their GINI coefficient. The Netherlands has a GINI index of 29, amongst the lowest in Europe (World Bank, 2016), see figure 2 and 3.

- Few case studies have estimated the WTP for electricity based on income levels (quintiles division) and even taking into account urban and rural correlations (Adam et al., 2013; Bose and Shukla, 2001). These studies were undertaken in developing countries and based on surveys. They show that electricity has a positive relationship with income levels and Bose and Shukla (2001) found that electricity represents a proportionally higher percentage of domestic household expenditures in urban that rural areas.

- The WTP can be expressed for a country-level as a weighted average (based on income distribution for each household income quintile, % of electricity expenditure and electricity consumption.

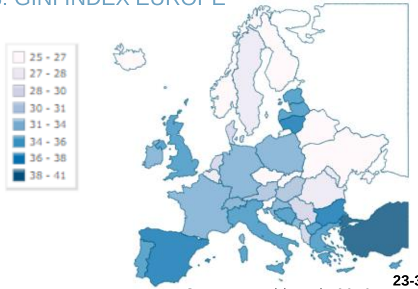
$$\sum_{i=1}^{5} WTP = \frac{HH\ Income_i\ x\ \%\ elect.expenditure_i}{Electricity\ consumption_i}\ x\ \%weight\ (HH\ distribution)$$

Figure 2: PERCENTAGE SHARE OF INCOME BY QUINTILE (NETHERLANDS AND RWANDA)



Source: World Bank, 2011

Figure 3: GINI INDEX EUROPE



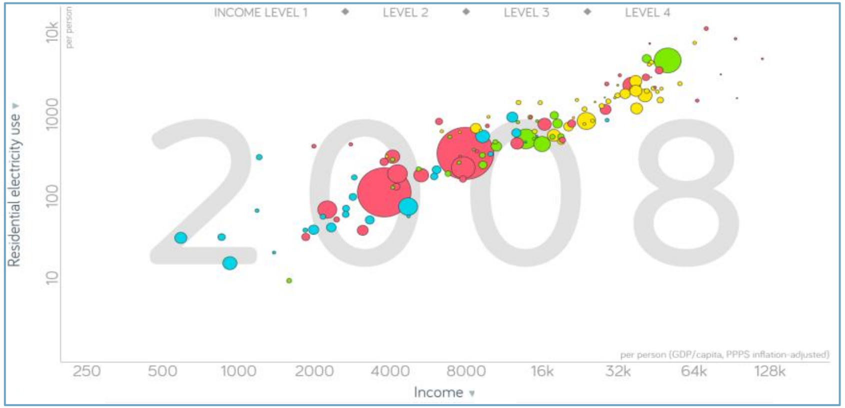
Source: World Bank, 2016

ANALYTICAL METHODS
AGGREGATED APPROACH

- ELECTRICITY CONSUMPTION AND EXPENDITURE – Empirical studies show that electricity use has a positive relationship with income levels, see figure 4. Those with high income often have more electrical appliances, hence consuming more electricity (Carlsson and Martinsson, 2008). Then WTP is higher based on the electricity consumption, as shown in a the case in Senegal (Camblong et al., 2009).

- However, depending on the area of residence and geographical regions, different classes of consumers pay different amounts for the same quantity of electricity (Nkosi and Dikgang, 2018). In India, rural domestic consumers bear significant coping costs in the absence of reliable electricity supply (TERI, 2017). The World Bank (2010) found that consumers in rural areas where electricity demand is unmet are willing to pay higher tariffs for short-term power purchases. Similarly, Abdullah and Jeanty (2009) shows that the WTP as a percentage of income is higher for lowest income groups. Likewise, in developing countries and specifically in rural areas, expenditure on energy represents a large part of the household total income. This shows the variations and complexity per regions and countries.

Figure 4: GDP PER CAPITA (PPP) VS RESIDENTIAL ELECTRICITY USE



Source: World Bank and WEO

- According to IIASA (2012), data for the U.S. and Japan suggest that once annual per capita income levels exceed $30k per capita, energy use no longer increases with GDP and total energy demand is largely a function of population and prices. Also, analyses show that income elasticity of the demand for energy is positive, meaning that rising incomes will lead to increased energy use (IIASA, 2012). However, the magnitude of these elasticities differs by stage of economic development. In developed countries, the estimated income elasticities tended to be less than one (e.g. a 10% increase in income would result in an increase in energy use of less than 10%).

APPLICABILITY
THE NETHERLANDS CASE

- The electricity expenditure per quintile is estimated in the Netherlands, using the price of electricity (€/kWh) as WTP, see table 1.

VARIABLES AND SOURCES

$$Electricity\ price\ = \%elect.expenditure\ x\ \frac{Income_{per\ capita}}{Electricity\ use_{per\ capita}}$$

  - Income share per quintile – *World Bank: Percentage share of income or consumption is the share that accrues to subgroups of population indicated by deciles or quintiles.*
  - Net national income – *World Bank: Adjusted net national income (constant $2010) is GNI minus consumption of fixed capital and natural resources depletion.*
  - Population – *Eurostat*
  - Electricity prices by medium size households – *Eurostat: This indicator presents electricity prices charged to final consumers.*
  - Residential electricity use per person – *Eurostat*

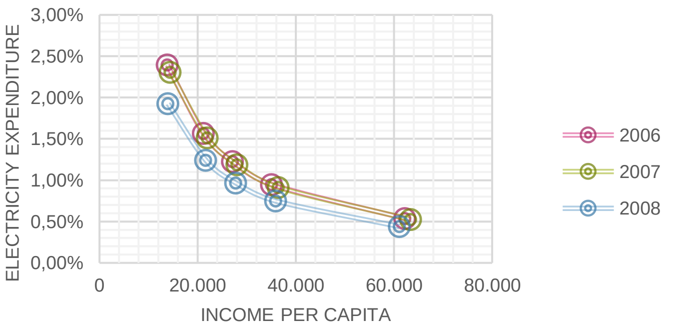
INSIGHTS ON FIGURE 5

- Electricity expenditure decreases with an increase on income levels.
- Electricity expenditure ranges between 0,4 – 2,4% per capita through 2006-2008
- The largest gap is between quintile 1 and 2 → difference of 0,8 (on average) and the gaps between the middle quintiles is about 0,3 (on average) and the gap between quintile 4 and 5 is 0,4 (on average).
- Gaps on electricity expenditure between different income levels are shorter over time.
- Over an income per capita of about €30,000 electricity expenditure decreases less sharply with an increase in GDP.
- In developing countries, households generally spend more on energy as the income rise (Prasad and Visagie, 2006). The most common used measure of energy poverty is that households spend >10% of their income in meeting their energy needs (Khandker et al., 2010; Department of Energy, 2012; Pereira et al., 2011; Winkler et al., 2011).

Table 1: ELECTRICITY EXPENDITURE PER QUINTILE LEVEL, THE NETHERLANDS 2006-2008

Electricity expenditure	2006	2007	2008
Quintile 1 (Lowest)	2,40%	2,30%	1,92%
Quintile 2	1,57%	1,51%	1,24%
Quintile 3	1,23%	1,19%	0,97%
Quintile 4	0,95%	0,91%	0,75%
Quintile 5 (Highest)	0,53%	0,53%	0,44%

Figure 5: INCOME PER CAPITA (PER QUINTILE VS ELECTRICITY EXPENDITURE, THE NETHERLANDS 2006-2008 (€2010)



GRID-CONNECTION VS OFF-GRID RESEARCH

- In developing countries, there is an inclination for the deployment of microgrids instead of connection to the grid. Two factors were found to be influential on this inclination:

- BREAK-EVEN GRID EXTENSION DISTANCE – It entails the distance where a microgrid is more cost-effective than the extension of the grid. A case of a village in Rwanda shows that extending the grid would be as costly as a microgrid deployment if the grid is within 3.37km from the village (Murenzi and Ustun, 2015). Based on a case study in Senegal, Camblong et al. (2009) quoted that a distance from the grid further than 10km is the reference figure which makes a microgrid cheaper than the conventional grid-connection.

- SERVICE LEVEL – A microgrid is more likely to be financially viable if it can provide a superior level of service (i.e. more reliable, more hours of electricity, more environmentally friendly) for a tariff that is similar and ideally lower than a household's current energy expenditures. Graber et al. (2018) undertook a study in India and found that consumer's preference is based most significantly in power, reliability and price (in order of strength), therefore they are more satisfied with microgrids and are willing to pay more, as grid expansion further stresses reliability and supply during peak hours. Many rural consumers connected to the grid have chosen to switch to microgrids, even though tariffs can be over 20 times higher, microgrids provide reliable service at predictable hours (World Bank/ESMAP, 2017).

- The insights above give an indication of the future role of microgrids in regions with no access to electricity. Their role as a viable solution can be eventually translated into developed countries when the systems become more cost-efficient and give possibilities of energy independency and producing, consuming and selling own electricity.

CONCLUSIONS

- There are significant differences on WTP drivers in developing and developed countries. The latter is mainly driven by the WTP to increase the provision of renewable energy or the value of reliability in electricity supply. Meanwhile developing countries' WTP studies are driven for by access to electricity and affordability. Nevertheless, based on empirical research, income levels, electricity consumption and geographical location influence both. In most studies, there is a positive relationship between income levels, urban areas and electricity consumption; which in turn may positively influence the WTP.

- Empirical studies in developed countries show that consumers are willing to pay more for renewable energy, and are also willing to trade some reliability for lower electricity bills. This emphasizes the role that microgrids can provide, being renewable-based and intermittent into some extent.

- Survey-based methods are used in all case studies to estimate the WTP for electricity, either for electricity access, renewable energy or reliability. The most widely used methods are Contingent Valuation (CV) and Choice Experiments (CE). The data from these surveys is then compiled into a database to determine an average WTP in monetary units.

- When applying the variables of the aggregated approach in the Netherlands, the electricity expenditure shows a decrease with an increase on income levels. This is aligned with empirical research in developing countries where poor households spend a higher proportion of their monthly income on energy (Prasad and Visagie, 2006). The WTP however, is more difficult to be estimated based on the electricity expenditure per income level, as it is also important to take into account other influencing variables per income level (i.e. electricity consumption, geographic location, socio-economic factors). Nevertheless, as shown in case studies in developing countries, WTP (as a percentage of income) is higher for lower income groups, as lower income groups value more electricity and this can also be related to developed countries (e.g. the Netherlands).

- At present, data is not fully available to be able to estimate the WTP in the Netherlands or other developed countries through an analytical approach. No macro-level analytical approach (e.g. equation-based) can provide an accurate WTP estimation, as differences in income levels, electricity consumption, urban and region areas are crucial aspects to be taken into account. Hence, a tailor-made WTP approach is required.

RECOMMENDATIONS FOR FURTHER RESEARCH

- FOLLOW-UP STUDY
  - A survey is crucial to understand the main local factors influencing WTP in the area of study. It is recommended to carry-out a CV survey study in the Netherlands to provide a more accurate estimation of WTP for microgrids; taking into account differences in urban and rural regions, income levels, electricity consumption, environmental awareness and other socio-economic factors. The study can be complemented with CE survey to value electricity attributes such as sustainability (i.e. renewable energy sources), reliability and independency (considering the ‘prosumer’ role).
  - A follow-up study in the Netherlands would also help to test the electricity expenditure values estimated in this study and to check if the WTP value corresponds to current electricity prices, and if the electricity expenditure decreases with higher income levels. Unfortunately, data on residential electricity use in the Netherlands is only available for the years 2006-2008, which limits the present analysis. Further recent data is needed on residential electricity use (and if possible, divided per income level) for better results.
  - The Netherlands is amongst the most equal countries in Europe, position 14th out of 39 countries (based on GINI index), therefore the differences in WTP amongst different income levels may not be very large. Hence, it is recommended to complement the follow-up survey study with a study in another European country with a higher GINI index for comparison purposes, such as Spain, with a GINI index of 36 and position 36th out of 39.

The Aardehuizen: *A community microgrid in the Netherlands. Read article “These Dutch microgrid communities can supply 90% of their energy needs” here: https://goo.gl/XdLJxM*

- In developing countries, microgrids represent a viable solution for access to electricity and their role is expected to grow in the future, which in turn will result in more cost-effective and efficient microgrids. This represents and opportunity for developed countries as a potential solution for a low-carbon and independent energy system. Therefore, further research on microgrids development in developing regions is needed as it may offer cross-learning effects.
- Regarding WTP estimation in developing countries, a division of households based on their electricity consumption levels can be very useful. ESMAP (2015) provides a tiers approach to divide households on their access to electricity services and electricity consumptions, however no macro-level division or study is available on the relationship between these multi-tier levels and income levels. This can provide a reference across countries for further research on WTP for grid-connection or off-grid electricity.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APPENDIX A: MAIN FACTORS INFLUENCING WTP

FACTOR	EXPRESSED IN	LEVEL	REGION	SOURCE
Income	GDP / Total expenditure	National / Household / per capita	All	World Bank
Income level	GDP per quintile / Income per quintile / GINI coefficient	National / Household / per capita	All	World Bank
Geographical location	% of population living in Urban and Rural regions / Leading and Lagging areas / Mega-city / Population density / Agglomeration Index	National / Household	All	World Bank, WDR (2009), MGI Cityscope (McKinsey)
Electricity consumption	kWh / Electrical appliances and equipment	Household / per capita	All	
Electricity expenditure	% of Income / GDP / Total expenditure	Household / per capita	All	See Appendix A
Electricity prices	€/kWh	National	All	Eurostat
Payment mechanisms	Collective vs individual / Voluntary vs. mandatory	National	All	Case studies
Reliability	Number of power outages, length, time of the day and season	Central grid / Mini-grid	All	Case studies
Back-up system or substitute	Extra payment on back-up system or substitute	Household	All	Case studies
Other socio-economic factors	E.g. age, education, family size	National / Household / per capita	All	World Bank
Renewable energy	% renewable share or emissions reduction (tCO2eq.)	Central grid / Mini-grid	Developed countries	Case studies
Energy independency	Disconnection from central grid	Household	Developed countries	Case studies
Environmental awareness	Knowledge of climate change and renewable energy technologies	National / Household / per capita	Developed countries	Case studies
Prosumer role	Possibility to produce, consume and sell own electricity	Household	Developed countries	N/A
Access to electricity	% of population with electricity access / Multi-tier matrix for access to household electricity services	National / Household	Developing countries	World Bank, ESMAP (2015)
Grid proximity	Break-even grid extension distance	National	Developing countries	Murenzi and Ustun (2015), Camblong et al. (2009)

APPENDIX B1: CASE STUDIES (RENEWABLES)

CASE	AIM	WTP	METHOD	SOURCE
Australia	WTP for an increase in electricity generation from renewable sources	$28 per quarter (average)	CVM	*Ivanova (2012)*
China	WTP for renewable electricity	US$2.7-3.3 per month (average)	CVM	*Guo et al. (2014)*
England	WTP for a renewable energy program to internalize costs for energy security, climate change and air pollution	Higher value	CE	*Longo et al. (2008)*
Finland	WTP for energy from wood	€261 per year	CE	*Kosenius and Ollikainen (2013)*
Germany	WTP for a more environmentally friendly electricity mix (16% renewables)	Higher price	CE	*Kaenzig et al. (2013)*
Greece	WTP for an expansion of 10% of renewables in the electricity mix	€26.5 per quarter	CVM	*Ntanos et al. (2018)*
Italy	WTP for renewable energy	€4.62-8.05 per 2 months (median)	CVM	*Bigerna and Polinori (2014)*
Japan	WTP for renewable energy	US$17 per month (median)	CVM	*Nomura and Akai (2004)*
Norway	WTP between imports of electricity from coal-fired power plants vs building more hydro power, wind farms or gas-fired plants	Norwegians preferred wind power	CE	*Navrud and Braten (2007)*
Scotland	WTP for renewable energy projects with no increase in air pollution	£14.40 per year	CE	*Bergmann et al. (2006)*
Spain	WTP for a green electricity program	€29.91 per month (average)	CVM	*Hanemann et al. (2011)*
United States	WTP for a provision of 10% of renewable energy in the energy mix	$14 per month (average)	CVM	*Mozumder et al. (2011)*
United States	WTP for a 1% increase in renewable energy and 1% decrease of emissions	$0.11 and $14.22 respectively per year (median)	CE	*Roe et al. (2001)*
United States	WTP for a 25% hydro power supply vs no renewables	¢1.46 per kWh	CE	*Goett et al. (2000)*

APPENDIX B2: CASE STUDIES (RELIABILITY)

CASE	AIM	WTP	METHOD	SOURCE
Australia	WTP to avoid specific restrictions on service supply quality (i.e. reliability) in residential electricity	$43 to avoid a one-time, two-hour power outage (highest average). Customers value fewer and shorter outages	CE	*Hensher et al. (2014)*
Belgium	WTP for continuous power supply	No WTP for extra reliability of electricity supply (considering that outages are rare in the area – 2 outages or less in 2 years). A significant share is willing to switch to a lower reliability level if compensated with a small electricity bill discount.	CE	*Pepermans (2010)*
Hong Kong	Value residential outage costs	More than half respondents would have traded some reliability for a lower electricity bill (considering that reliability is high).	CV	*Woo et al. (2014)*
The Netherlands	Value social costs of a lower reliability level	The social cost of the present reliability level (customers without electricity fir about 30 min per year) is €2.80 per household (on average). Households prefer short outages and a compensating discount on the electricity bill.	Conjoint Analysis: survey respondents are asked to rank possible outcomes based on variation of attributes of the good.	*Baarsma and Hop (2009)*
Sweden	WTP for reductions in power outages	WTP increases with the outages duration and is higher if they occur during weekends and winter months.	CE	*Carlsson and Martinsson (2008)*