Defining an Advanced Metering Infrastructure (AMI) Rollout Strategy For Colombia

January 2017

Prepared for:

Unidad de Planeación Minero Energética (UPME)

British Embassy Colombia

Our mission is to accelerate the transition to a sustainable, low-carbon economy

Executive Summary

- An AMI system would **reduce electricity losses and improve competition between suppliers.**
- **Interoperability** would be facilitated through **a single national requirement on functionality of an AMI system**.
- Our recommendation **would be for an organisation to be established to manage and control consumer data.**
- **Distributed Network Operators (DNO) to lead roll-out implementation:**
  - Roll-out to be led by regional DNO
  - DNOs to procure together where practical to obtain a discount and to achieve economies of scale for meter manufacturers
- **Proven technology option:**
  - Meters to only monitor electricity, not sufficient need for gas/water
  - Not sufficient need for an in-home display considering the cost

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The purpose of this project is to determine an appropriate AMI roll-out strategy for Colombia

- **Colombia's AMI objective:**
  - To reduce losses (technical and non-technical), improve network planning, integrate renewable energy technology at optimal cost, provide new services to customers and further the development of smart cities.
- **Current AMI initiatives in Colombia:**
  - To date, one city has introduced a pilot trial of an AMI system, and several utilities in Colombia are testing AMI systems. However, the technology is still relatively nascent in the Latin America region.

Source: UPME and Carbon Trust Analysis

Our research identified a number of priorities for a national AMI System that together reduce energy demand

Colombia AMI Roll-out Priorities

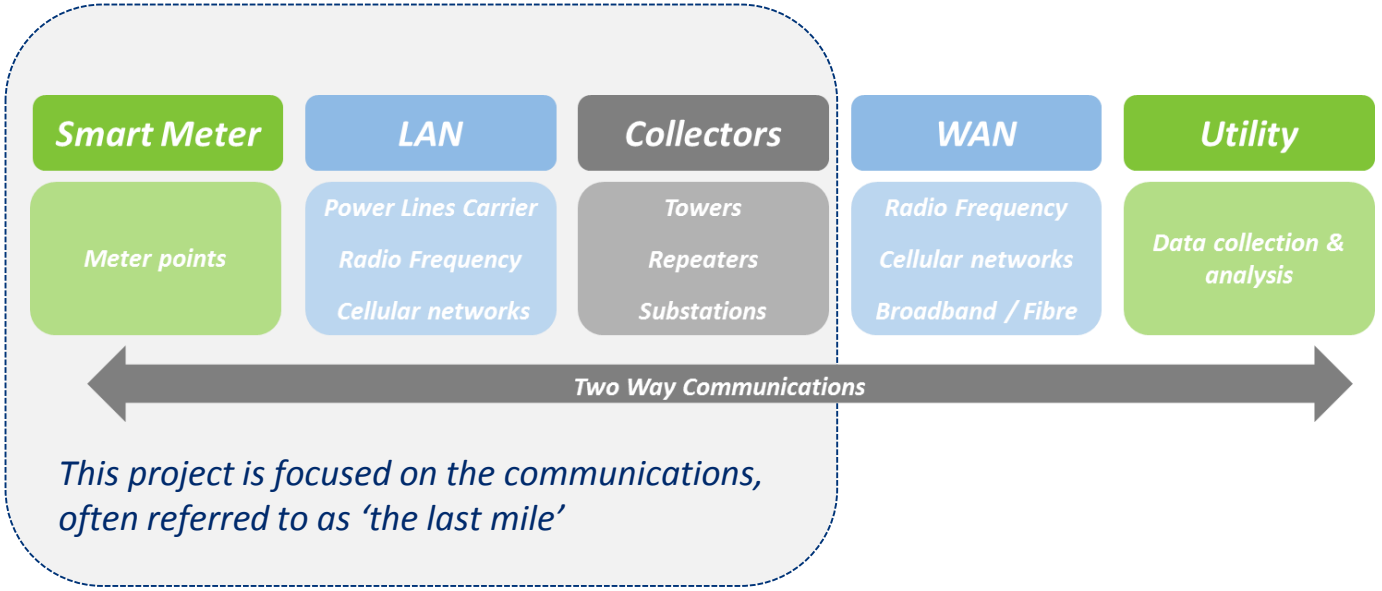
1 Reduce non-technical losses	Short term
2 Enhance retail competition	Short term
3 Improve network planning	Short term
4 Reduce technical losses	Short term
5 Provide consumer info	Medium term
6 Reduce meter reading costs	Medium term
7 Decrease operating costs	Medium term
8 Reduce CO_2 emissions	Medium term
9 Reduce outage time	Medium term
10 Allow smart tariffs	Long term
11 Allow ANM	Long term

Reduce cumulative energy demand

Source: UPME and Carbon Trust Analysis

Defining an AMI System

- AMI systems monitor and control electricity distribution grid activities, ensuring the efficient and reliable two-way flow of electricity information between consumers, utilities and generators.

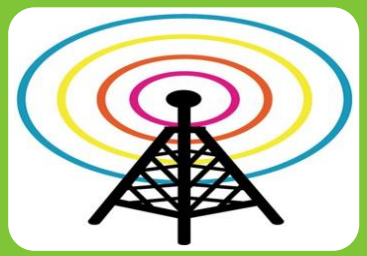


Source: Carbon Trust Analysis

Typically three types of AMI communication platforms deployed globally

Power Line Carrier (PLC) systems enable data to be transmitted from the meter through pre-existing electricity wiring and up the power line directly to a collection point, usually in the distribution substation feeding the meter.

Radio Frequency systems (RF) transmit data by wireless radio frequency. Meter points can connect to other nearby meters to form an RF 'mesh' of network coverage which then uses points closest to the collector to transmit data from multiple meters. Alternatively meters can talk directly to the collector in a 'point-to-point' RF design. Data is then packaged by the collector and sent to the utility for processing at a central location



Cellular AMI systems transmit data using the mobile telecommunications network (e.g. GSM/GPRS). In most cases this means using a commercial cellular network to connect smart meters to the network, which then transmit information either to a collection point or directly to the utilities data processing sites.

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  - Conclusions for a high level roll-out plan for Colombia

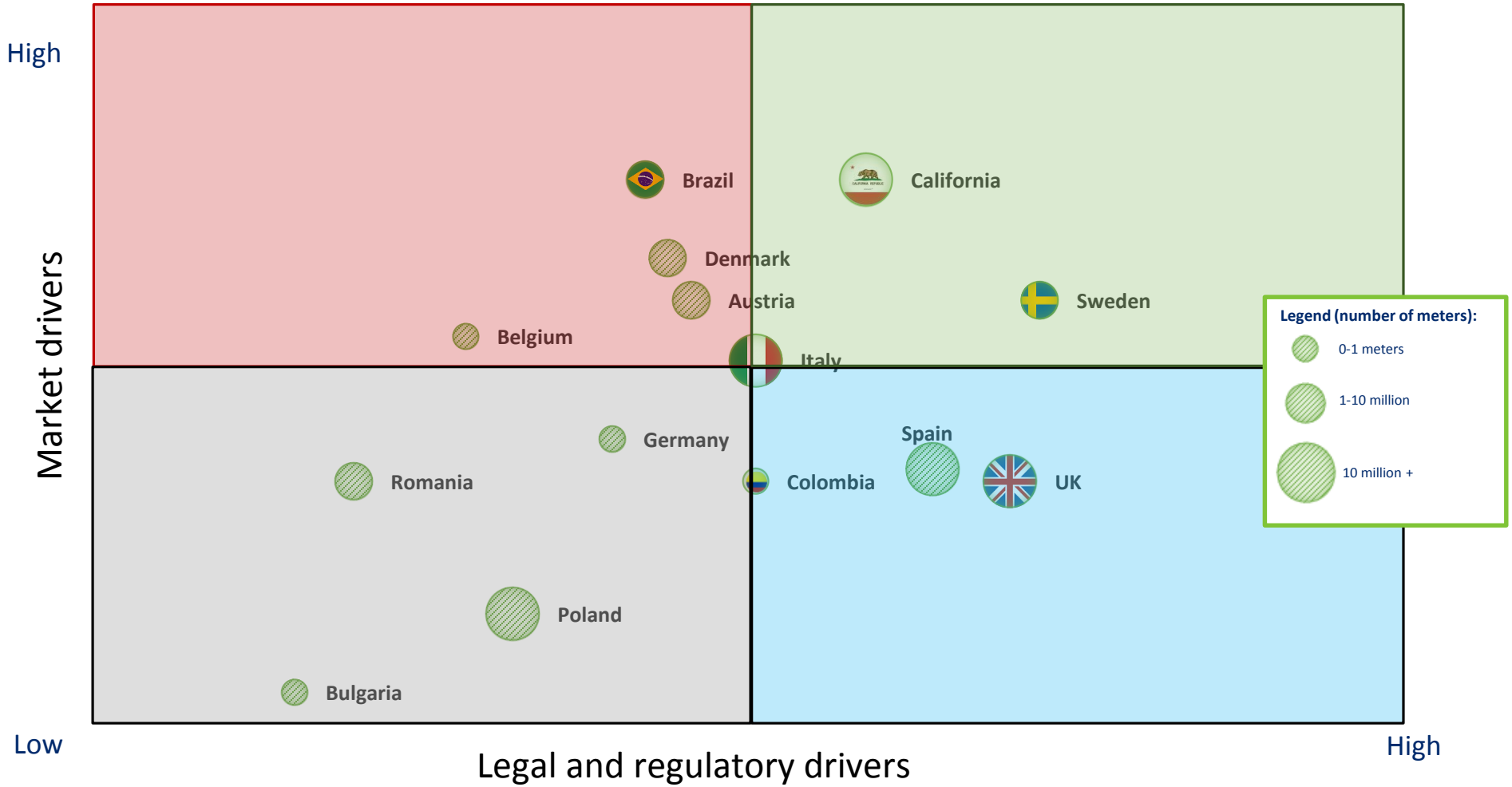
Learning from AMI roll-outs in other countries help to guide the future plan for Colombia

- Selection criteria based on:
  - Examples that utilise different communication technologies
  - Countries with comparable energy generation, distribution networks and energy markets to Colombia
  - Countries with good insights on the AMI roll-out

- AMI communication platform / Roll-out strategy in selected countries (as agreed by UPME):
  - Italy (PLC / National)
  - UK (Cellular and long range radio communications / National)
  - Sweden (Mixed communication technologies / Regional)
  - USA, California (RF / Regional)
  - Brazil (Mixed communication technologies / Regional)

Country AMI deployment is driven by combination of market and regulatory drivers

Development of AMI systems has been European and US focused. Countries marked with a flag denote the countries we have undertaken analysis on.



Source: Data partially sourced from GTM research for European countries. Brazil, California, Colombia, Italy, UK and Sweden's position was determined through Carbon Trust country analysis

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The UK opted for a high functionality system based on cellular and long range radio

AMI Objectives:

- Reduce domestic energy consumption through behaviour change and eco-efficiency product selection
- Improve energy network operation and maintenance
- Support the UK meet its 2020 carbon reduction obligations

Roll-out procedure:

Status: Deployment in progress

Drivers for roll-out: Regulation

Market Penetration: 100% by 2020

Project payback: 9.5 years

Source: Carbon Trust Analysis

Main UK Insights

Policy & regulation: Smart Meter Equipment technical Specification , meter and communications to ensure common functionality and standards, although

Network functionality: Dual meters monitor gas and electricity consumption to utilise economies of scale to avoid investment in two meter solutions.

Data management: Competitive procurement of an independent in in principle a good plan, but complex DCC implementation has delayed the roll out

Implementation: Retail-utility led roll out has also delayed implementation as utilities have has to build both the skills nor the staff to implement on a “fragmented” basis (i.e. on street-by-street“)

Roll-out plan: Cellular network rolled out to Southern UK and RF network rolled out to Northern UK to ensure best possible communication option for local characteristics and reliable network coverage.

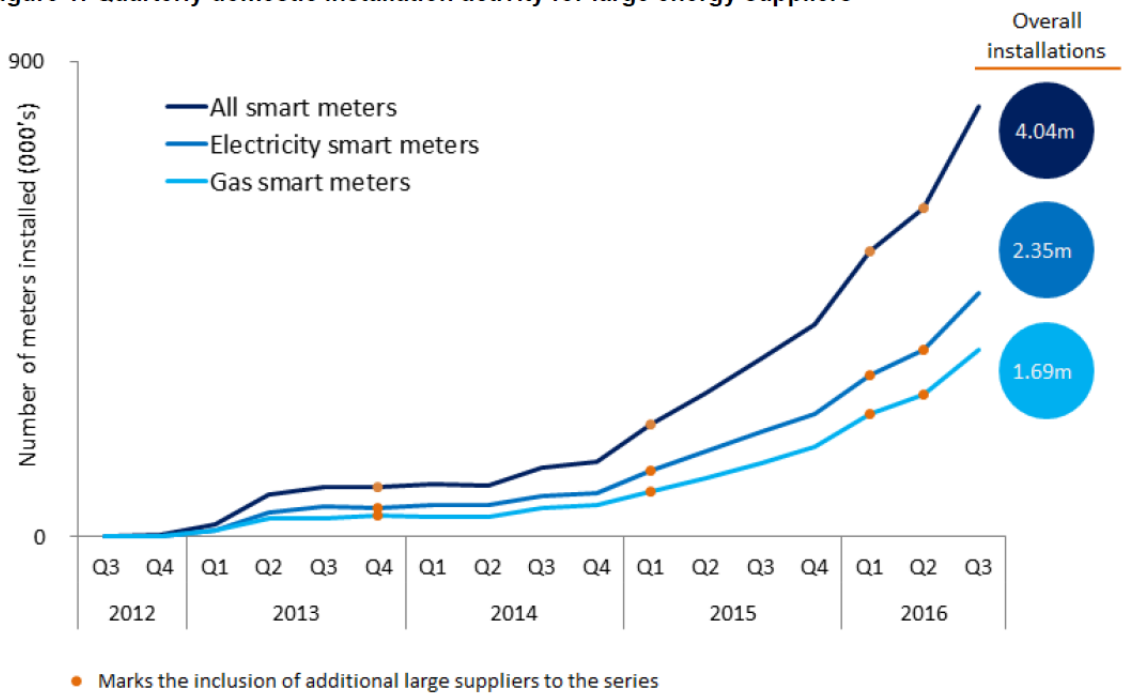
Communication technology: Expensive high feature system chosen based on a cost benefit analysis relies on an ambitious assumption on how much energy will be saved by consumers.

Stakeholder engagement: Consumer organisations established to facilitate roll-out process, both to ensure consumers understand and support the roll-out.

Source: Carbon Trust Analysis

The UK roll out is significantly delayed

Figure 1: Quarterly domestic installation activity for large energy suppliers



Notes

- The UK is in effect still in the "foundation stage" of its roll out with SMETS2 meters not available until Q2 or Q3 of 2017
- All meters installed to date are SMETS1 which has added complexity, cost and delay to the UK roll out
- Delays have been caused by the time taken to agree the SMETS2 standard, the time taken for retail utilities to get up to capacity and the time taken for the DCC to be available

The DCC implementation has been delayed several times

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Smart meter IT system delayed until autumn

By John Moylan
Industry correspondent, BBC News

17 August 2016 | Business

Share

A key IT project at the heart of the UK's national smart meter roll-out programme is facing further delays.

The government has confirmed that the communications infrastructure which links smart meters to energy suppliers will now not be ready until the autumn.

Notes

- The £2.5 billion implementation of the DCC has been hit by three delays due the complexity of technical specification including 15 minute read capability
- This has extended the foundation stage and led to a large number of SMETS1 meters being installed, further adding to system complexity and cost

Pros and cons of the UK rollout

Pros	Cons
• Central data management agency (DCC) spurs competition and third party services	• Structure of competitive UK energy market does not support and efficient roll out – energy retailers operate call centres rather than field engineers and have customers scattered across the country
• A properly resourced (2% of the total implementation cost) consumer engagement strategy	• The lengthening of the foundation stage has led to more SMETS1 meters being installed than expected adding to cost and complexity
• Installations to date are meeting the 3% energy efficiency target in the Impact Assessment	• The DCC initial build was over-ambitious and has led to delays

Sweden opted for a combination of PLC, RF and Cellular

AMI Objectives:

- Raising consumer awareness on energy consumption, particularly during the winter months, when Sweden is heavily reliant upon electric heating
- Simplification of the supplier switchover process
- Information based on actual energy consumption rather than on estimations

Roll-out procedure:

Regulatory driven

Monthly reading requirement	Hourly reading requirement
2003 – 2006	2006 to 2009

Status: Deployment complete, second stage of roll-out to begin

Driver for roll-out: Regulation on monthly and hourly metering lead distribution companies to roll-out an AMI system. Choice of technology stipulated by DNO's hence multiple communication technologies.

Market Penetration: 100% by 2020

Source: Carbon Trust Analysis

Main Sweden Insights

Policy & Regulation: Changeable regulations on meter reading requirements led to additional cost in roll-out.

Implementation: Meter ownership by DNO effective as no need to switchover meter when a customer switches supplier. Collective purchasing of AMI equipment by smaller suppliers collectively achieved cost savings. Pilot phase of testing was required for first three years to resolve communications issues with the meters.

Communication technology: PLC communication found to be less reliable than other communication options and RF systems found to be difficult to maintain in extreme climates. Multiple communication technologies add expense but can utilise best solution for local area.

Source: Carbon Trust Analysis; Smith, 2013; ISGN, 2013; NordReg, 2013

Pros and cons of the Swedish rollout

Pros	Cons
• Strong energy efficiency benefits have been delivered early	• Lack of foresight in regulation added costs to the roll out
• Smaller suppliers clubbing together brought economic benefits	• Utilities installed proprietary systems which are not interoperable
• Utilities able to choose the communications technology that best suited their customer base and existing infrastructure	

Italy was the first country to roll-out an AMI system on a national scale, using PLC technology

AMI Objectives:

- Reduction in non-technical losses
- Greater distribution systems availability for customers
- The ability to offer time-of-use tariffs to customers

Roll-out procedure:

Status: Deployed

Roll-out implementation driven by: Government regulation with Utility support

Market Penetration: 100% by 2021

Project payback: 5 years (1st roll-out)

Source: Carbon Trust Analysis; ISGN, 2013

Main Italy Insights

Policy & Regulation: Initial roll-out driven by the national utility Enel, later in 2006 roll-out mandated by government. The roll-out timeframe was realistic.

Implementation: Italy rolled out its AMI system at a relatively low cost at €70/meter in a relatively trouble free way. A common meter standard was established by Enel to ensure interoperability.

Communication technology: PLC found to be less reliable than alternative technologies.

Source: Carbon Trust Analysis; ISGN, 2013

Italian roll-out successes in brief

CO2 emissions reduced by more than 30,000 tonnes by 2010

Financial savings of more than €500 million per annum

Technology transfer: Enel the Italian utility has sold the technology developed in Italy to Spain

Source: ISGN, 2013; Smith, 2015

Main benefits brought from the Italian AMI solution

- Cost of service per customer decreased from €80 to €48 post AMI roll-out.
- Quality of service improvement:

Average outage time (minutes/customer/year)	
2001	2011
128 minutes	46 minutes

- Italy's AMI solution, alongside its feed-in tariffs, has been a key enabler in the large scale growth of wind and solar energy generation in Italy

Source: AT Kearney, 2012

The second Italian roll-out due in 2018 – more functionality & benefits

- Roll-out combines electricity and gas metering
- Direct communication with third party devices will now be available in the home
- Fibre optic comms will dramatically improve system reliability and functionality

Source: Carbon Trust Analysis; Martini, 2015

Pros and cons of the Italian rollout

Pros	Cons
• Relatively simple implementation efficiently roll out	• Dominant utility Enel effectively wrote the rules
• Delivered objectives and early benefits	• Roll out didn't support spur competition
• Short ROI	• Italy locked into a "semi-proprietary" technology
• DNO-led "street-by-street" roll out	
• Second roll out adds new functionality	

California sought a regional RF network

AMI Objectives:

- Incentivise demand management and reflect the true cost of the summer peak load
- Encourage the adoption of PV
- Adoption of new technology including electrical vehicles, heat pumps and energy storage

Roll-out procedure:

Regulatory driven

Hourly reading requirement

2006 to 2013

Status: Deployed

Roll-out implementation driven by: Government regulation with Utility support

Market Penetration: 100% by 2021

Source: Carbon Trust Analysis

Main Californian Insights

Policy & Regulation: Regulation for roll-out driven by state government, but local utilities responsible for implementation. Poorly managed mandate and implementation forced regulators to offer customers an opt out.

Implementation: Considerations were taken for the impact on labour markets in California, so re-training programmes were implemented. Innovation and third party developers were invited to develop solutions for the AMI roll-out, e.g. energy based applications.

Communications Technology: The Californian government demanded a proven AMI technology option and therefore utilised an RF network.

Source: Carbon Trust Analysis; ISGN, 2013; Edison, 2012

Pros and cons of the California rollout

Pros	Cons
• California leads the world in the implementation of PV, storage and EVs – all enabled by the smart meter roll out	• AMI systems deployed prevent retail competition
• Fully regulated market means that utilities were able to procure existing proprietary solutions with no need for interoperability	• Challenges in implementing TOU tariffs caused significant customer backlash forcing the regulator to offer an opt-out
• Utility-owned RF network simply added to utilities regulated asset base with simple capability requirements set by the regulator	
• Local labour and technology favoured during the roll out	

Brazilian roll-out driven by utilities

AMI Objectives:

- Reduce non-technical losses, particularly meter tampering and illegal connections
- Improve network efficiency

Roll-out procedure:

ANEEL and Brazil's Ministry of Science and Technology have announced an aim to deploy 63 million smart meters by 2021. No firm national plan has been announced, small regional projects have been implemented by utilities.

Government targets for AMI

2009 to 2021

Status: Only new builds mandated to have an AMI system. National roll-out yet to be implemented.

Roll-out implementation driven by: Utilities

Market Penetration: 100% by 2021

Source: Carbon Trust Analysis

Main Brazilian Insights

Policy & Regulation: Targets established for an AMI system but no federal regulations established, and therefore lack of clarity on roll-out. Legislative research and development targets for energy generators, distributors and network companies has led to investments in AMI technologies.

Implementation: Individual regional roll-outs undertaken by utilities, leading to multiple communication solutions. An accredited list of smart meter equipment manufacturers has been set up to provide favourable interest rates for investments.

Source: Carbon Trust Analysis

Pros and cons of the Brazil rollout

Pros	Cons
• Nine pilots have been implemented to assess technology and customer behaviour	• Lack of a national mandate, or incentive regulation, has led to limited activity. • Consumers dictate the pace of implementation should they choose to move to the “white” TOU tariff
	• Utilities unable to implement AMI in some locations due to safety concerns

Common learnings and recommendations for Colombia

Policy & Regulation: Regulations to be established on the functionality and interoperability of the AMI system defined by the government. Important to avoid a change of policy as this can add expense to the roll-out.

Combined infrastructure: Not sufficient need in Colombia to combine an electricity meter with that of another infrastructure, such as gas or water.

Implementation: Roll-out to be driven by DNO and a pilot phase for the roll-out should commence for the first two to three years to test communication options, and to develop and train personnel for the installation procedures.

Communication technology: PLC is a cost effective communication technology option, although reliability is questionable. Difficulties have been noted in Colombia with PLC due to the number of transformers. RF technology could be installed in more rural locations and areas with poor electricity infrastructure.

Data management: An independent entity should be established to manage consumer data to ensure suitable data controls and ensure adequate cyber security, essentially replicating the UK Data Communications Company.

Interoperability: Interoperability should be defined by government to ensure system compatibility and common functionality. Italy's Meters and More Solution is a best practice example of encouraging a common standard for AMI equipment.

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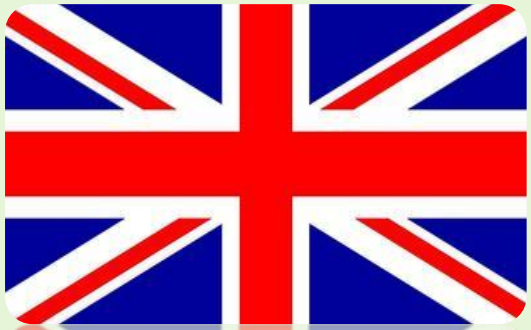
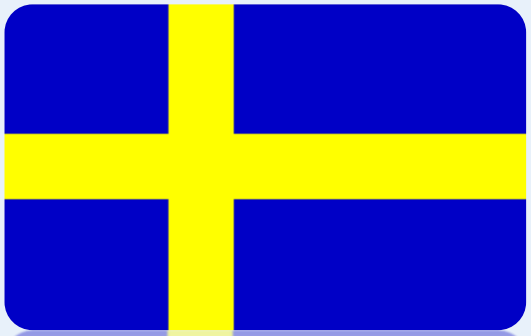
National or Regional?

National:



Regional:



Evaluation of national and regional roll-outs

National (UK)	Regional (California)
More achievable economies of scales: • Operation and investment. • Design of roll-out cost met by greater number of users. • Installation (cost of training installers). • Market outreach. • Data security and management cost spread across a larger population. • More expensive technology options more accessible. • National regulation potentially less complex than several regional regulations. • Wider industry standards. • Investment and authority to progress decisions (albeit potentially slow to pass legislation and adapt the design). • Universal system compatibility (inter-operability). **Fairer:** • Investment not dependent on local area wealth – e.g. an urban area may be able to afford higher functionality system. • Equal treatment given to all households nationally.	**Tailored roll-out strategy:** • More likely that the right technology will be chosen for each location. • Potential lower installation cost per meter due to more bespoke solution for each area. However, reduced economies of scale. • Installation engineers can potentially be trained quicker and sourced from other regions. • Fewer stakeholders to manage. • Potentially greater consideration of end users in design of network. • More dynamic to respond to issues with the design of network and likely to have greater community participation. • In addition, lower costs to adapt the design of the roll-out

› **Conclusion**: We would recommend defining the functionality and the investment cost nationally and allowing the regional DNO / utility to manage the installation procedure.

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We believe the key features of a smart grid system are:

Data operability: Data distributed from the meter to the distribution network is accurate, reliable and is only visible to the relevant stakeholders. This is important because data should only be available to a select group of stakeholders, who either need to access the data for billing purposes or have the consumer's permission.

Inter-operability: Defined as the ability of a system to work with one or more other systems without considerable investment in time or finance. Systems in an AMI network need to be able to easily communicate with one another to ensure data transfer is reliable and fast, whilst avoiding bespoke solutions that could add additional costs and complications to the system.

Cyber security: Refers to the protection of computer systems from the theft or damage to hardware, software or the information on them, as well as from disruption or misdirection of the services they provide. Insufficient levels of security could lead to undesirables accessing energy data.

Combined infrastructure: This is the process of combining multiple infrastructures into one solution. Economies of scale can be utilised by allocating the investment cost across a greater number of networks. Potentially this can lower the cost per household and can increase the favourability of a more advanced technology option.

Summary of best practice recommendations for Colombia

Best Practice	Recommendation
Data operability	• Replicate the UK Data Communications Company. Important for agreement to be made with the Colombian Data Protection Agency, a data management entity could be formed under this organisation. Our analysis suggests a future FCO Prosperity Fund project could go into additional detail in setting up this agency in the country.
Interoperability	• The Meters and More solution is a best practice example of meter manufacturers. However, it would be wrong for us to specify that Colombia should adopt this system as that may favour a particular meter solution supplier. Interoperability regulation should be included in the national roll-out to ensure system compatibility.
Cyber security	• Replicating the DCC organisation could allow Colombia to have a dedicated agency responsible for oversight of cyber security. An option could be to mandate the ISO 27001 standard. Consideration needs to be taken on maintaining sufficient levels of security with maintaining an economic network operation cost.
Combined infrastructure	• Our analysis suggests Colombia does not warrant a gas network. However, synergies could be found in combining the smart meter roll-out with a cellular or broadband network roll-out.

Best Practice: Data Operability

› Challenges:

Data access	•	Complication on how to define access rights.
	•	Sufficient legislation or penalties need to be in place for preventing unauthorised access.
Data quality	•	Data transfer lapses, this could be attributed to a power outage or weather impacting the communication infrastructure.

› Best practice:

Solutions
UK Data Communications Company (UK) to manage AMI data: • Aides consumer changing suppliers. • Has the authority to share metering data with network companies. • Facilitates efficient network management. • Customers can opt to share their energy usage data to third parties through the DCC, e.g. to obtain a more competitive tariff.
Italian Regulator AEEG set defined rules on data operability: • Rules on data security to prevent unauthorised access. • Dedicated security key per smart meter. However a **limitation here was that all of the smart meters had the same security key. Second roll-out has corrected this issue.** • Data accessible on a range of devices – website, smart phone, optional in-home display.

› **Recommendation for Colombia:** Replicate the UK Data Communications Company. **Important for agreement to be made with the Colombian Data Protection Agency,** a data management entity could be formed under this organisation.

Best Practice: Inter-operability

› Challenges:

Consumer switching	•	A key feature of an AMI system is to promote retail competition by allowing consumers to change energy suppliers quickly, easily and at minimum cost and disruption. An incompatible smart meter system could potentially lock a consumer into one utility and create an undesirable monopoly energy market.
Ownership of assets	•	If owned by the utility costs should be minimised when transferring the equipment from one supplier to another.
Smart network compatibility	•	Definition on the accessibility of minimum requirement of information that can be accessed by all consumers.

› Best practice:

Solutions
SMETS1 and SMETS2 meter standards: • UK roll-out has two phases of meters that meet a certain level of functionality specified by the UK regulator.
'Meters and More' standard for AMI equipment in Italy: • Enel and Endesa took a formation of an international non-profit association to define interoperability standards in Europe. • Project has received funding from the EU to develop a uniform protocol on data transfer between meters and central operators.

› **Recommendation for Colombia:** The Meters and More solution is a good example of defining interoperability in an AMI system. Interoperability regulation should be included in the national roll-out to ensure system compatibility. However, it would be wrong for us to specify that Colombia should adopt the '**Meters and More'** system as that may favour a particular equipment supplier.

Best Practice: Cyber security

› Challenges:

System requirements	• Sufficient system requirements for security and encryption for the AMI network needs to be implemented that conforms to an international standard such as ISO 27001.

› Best practice:

Solutions
UK GCHQ Intervention: • The UK electronic intelligence agency built in additional security measures into the meter. • DCC restricts access to the data and undertaking security tests on the network. • All providers have to meet the ISO 27001 protection standard and are audited. • Regular security audits are undertaken to identify and mitigate any new threats.
California: • Energy Data Access Committee (EDAC), which is a non-adjudicatory body established to receive and advise on data request issues that arise, formed from data stakeholders, including a seat for each of the IOUs, the CPUC, ORA, CEC, Local Governments, Consumer Advocates, Academic Researchers, and rotational interested parties.

› **Recommendation for Colombia:** Replicating the DCC organisation could allow Colombia to have a dedicated agency responsible for oversight of cyber security. An option could be to mandate the ISO 27001 standard. Consideration needs to be taken on maintaining sufficient levels of security with maintaining an economic network operation cost.

Best Practice: Combined infrastructure

› Challenges:

Variable need for metering	• In Colombia we do not believe there is sufficient need for gas metering due to the ability to meet demand through gas storage.
Multiple network providers:	• Need to allocate cost and maintenance accordingly to each infrastructure manager. • Investment and adaptation of the network can be dependent upon agreement with multiple stakeholders.

Best practice:

Missed opportunities

Italian second smart meter roll-out with ultra fast broadband:
Italy is now in the process of rolling out the second phase of the smart meter programme replacing the PLC lines with fibre optic technology. Enel the Italian Utility has set out that its infrastructure is open to other operators. However the Italian communications company Telecom Italia has opted to install its own network to avoid the loss of 15,000 jobs. Therefore two competitive networks are to be installed resulting in additional cost and disruption.

UK cellular technology remote areas coverage:
A new cellular network is being built solely for the use of smart meters to cover more remote areas. There could be extensive social and economic benefits in combining the cellular roll-out with increased network coverage in rural areas.

› **Recommendation for Colombia:** Our analysis suggests Colombia does not warrant a gas network. However, **synergies could be found in combining the smart meter roll-out with a cellular or broadband network roll-out**.

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Existing Initiatives in Colombia

Objective	Phase 1 (0 – 5 years)	Phase 2 (5 – 10 years)	Phase 3 (10 – 15 years)	Impact on roll-out
AMI (Advanced Metering Infrastructure)	**Energy network covered:** 58-70% **Demand side aims:** Remote lecture, losses management, demand knowledge, power limitation.	**Energy network covered:** 65-88% **Demand side aims:** Hourly tariffs and distributed generation.	**Energy network covered:** 73-100% **Demand side aims:** Active Network Management, Automated Demand Response.	Targets are realistic.
ADA (Advanced Automated Distribution)	2,7-3,3 interrupters per circuit.	4,2-5,7 interrupters per circuit.	Self-healing in the interrupters from phase 2.	**Low** – active network management is a secondary priority for Colombia.
DER (Distributed Energy Resources)	**Capacity**: 20-60 MW (0.1-0.2% of total generation) **Form**: Intermittent distributed generation in low voltage.	**Capacity**: 90-120 MW (0,4-0,5% of total generation) **Form**: Intermittent distributed generation in low voltage.	**Capacity**: 240-600 MW (1-2,5% of total generation) **Form**: Storage units.	**Low** – negligible impact on the grid due to the small amount of energy capacity.
EV (Electric Vehicles)	1-1.2% of the total number of vehicles sold.	3-4% of the total number of vehicles sold.	9-14% of the total number of vehicles sold.	**Low** – unlikely to have a sufficient impact on the grid until after 2030.
Fibre optic broadband roll-out	A fibre optic network is being installed to improve broadband connections within Colombia through the National Roll-out of Fibre Optic Cabling (2011) .			**Medium** – The network is installed to a node within each municipality. The distribution of the fibre optic communication to the 'last mile' would need to be reached in agreement with the municipality.

Source: Smart Grids Colombia Vision 2030 and Carbon Trust Analysis

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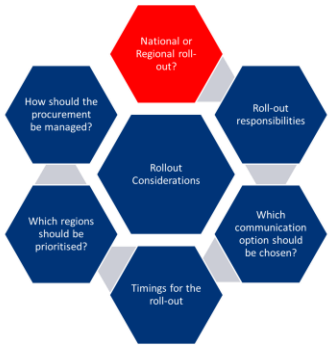
National or Regional roll-out?
How should the procurement be managed?
Roll-out responsibilities
Rollout Considerations
Which regions should be prioritised?
Which communication option should be chosen?
Timings for the roll-out

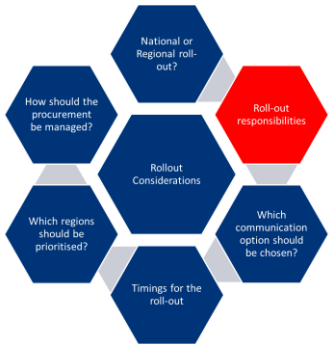


Government to define functionality and standards, regional DNOs to define AMI solution and installation procedure

CARBON TRUST

- **Recommendation for Colombia:**
  - Government regulation should stipulate the requirement for an AMI system on the performance, interoperability functionality and the roll-out duration.
  - The DNO should be responsible for the implementation of the roll-out. However, the appropriate AMI equipment should be determined on a regional basis along with the choice of installation engineers.

More detail on the responsibilities for the roll-out can be found on the next slide.



Roll-out responsibilities

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Organisation	Role	Detail
UPME (Unidad de Planeación Minero Energética)	UPME could actively support the development of the roll-out and could be responsible for national policy.	Establish and set policy.
		Define performance and interoperability functionality for AMI equipment.
CREG (Comisión de Regulación de Energía y Gas)	CREG could regulate the roll-out and could have oversight of reporting and timing.	Meter and communication equipment specification.
		Roll-out plan.
		Utility reporting.
		Assessment on the cost effectiveness of the roll-out.
DNO (Various)	DNOs will need to install and plan the network. They will need to set up procedures to manage the AMI network.	Implementation and programme management.
		Communication technology.
		Installation programme and training (and selection).
Stakeholder engagement	Organisation to be set up to manage the roll-out with consumers and businesses. This would replicate the UK's 'Smart Energy GB'.	Marketing and engagement.
		Raising consumer issues.
Data management	Oversight and management of the smart meter data sent from the meter to the utility to be managed by a new independent agency.	Organisation to be publically procured to manage data. who will control the data and manage.

Communications Option: *Three options to consider for Colombia*

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Power Line Carrier (PLC)

Pros:
- Can use existing infrastructure
- Can be cheaper than other options whilst offering sufficient capability
- Infrastructure remains under utility / DNO asset base

Cons:
- Long data transmission times (high latency)
- Less functionality than other communication options
- Questionable reliability
- Network interference

Suitability for Colombia:
This option would suit urban areas in Colombia

Radio Frequency (RF)

Pros:
- Near real-time communication and suitable for active network management
- Self healing, self forming and reliability in rural areas
- Possible to install regionally

Cons:
- Cannot be installed without a clean radio frequency
- More expensive than PLC due to the cost of equipment and construction
- Expensive for less dense regions
- RF mesh networks need to be installed on a mass scale to ensure sufficient network

Suitability for Colombia:
This option would suit remote regions, although potentially an expensive option

Broadband network

Pros:
- Reliability of data transfer
- Low data latency
- Economies of scale can be reached
- Can integrate with existing infrastructure

Cons:
- Requires coordination with stakeholders to manage network
- Investment and development of communications dependent on other stakeholders
- Not all meters have connection to broadband and it could be very expensive to connect

Suitability for Colombia:
This option would be suitable if it coincides with the fibre optic roll-out

PLC likely to be suitable communications technology for most regions, RF would be a good alternative for more sparsely populated regions

Which communication option should be chosen?

- **DNO should be left to procure the relevant technology option.**
- Our current assumption estimates that:
  - **A PLC system may be suitable for urban areas**
    - *Although our analysis suggests that PLC is less reliable than cable and fibre optic.*
  - **RF communication could be used for areas with a dispersed population**
- **National based AMI systems have normally utilised a combination of AMI communication technologies for in-fills.**

Timing: When should the roll-out be complete and how long should it last?

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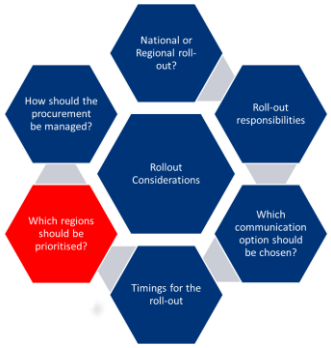
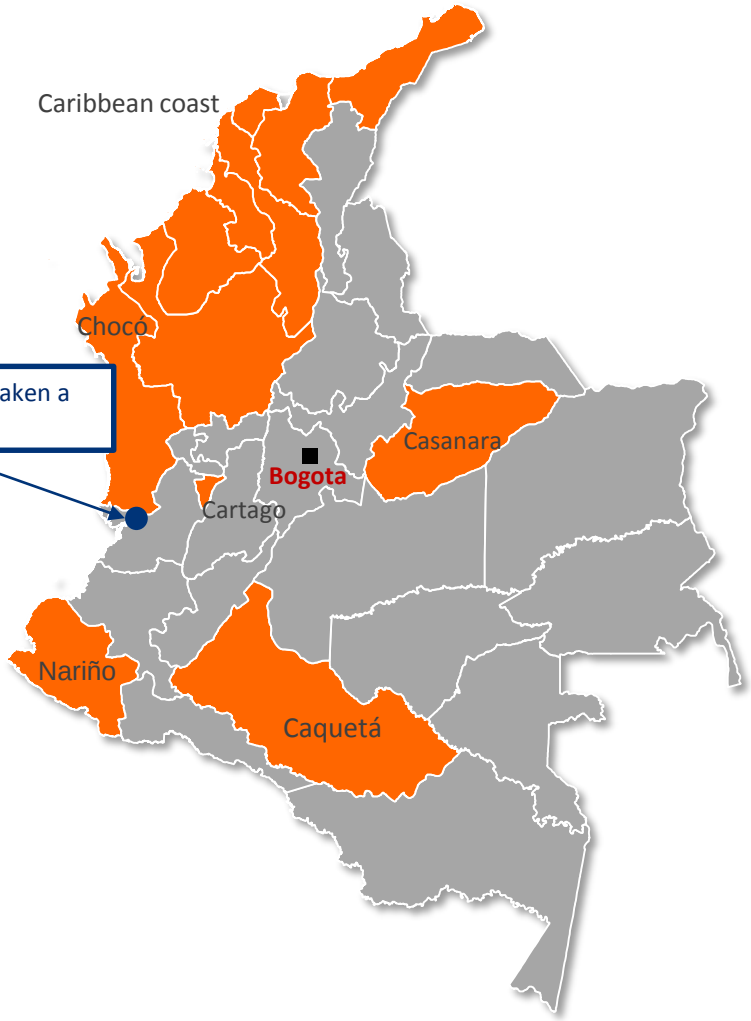
- **Start date**: Realistically roll-out unlikely to begin prior to 2019.
- **Roll-out duration**: 5 years
- **Follow on network**: It is expected that post 2030 a new AMI solution will be required. Different technology options may be more cost effective and new energy demands may lead to a different communication option being chosen.



Region Prioritisation:

Regions with high rates of non-technical losses

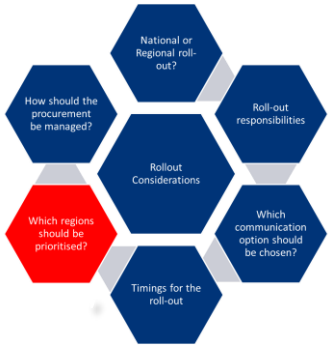


Note: Cali has undertaken a smart meter pilot

One of the key objectives of the AMI network is to reduce non-technical losses, therefore it may make sense to focus the installation on the regions with high rates of illegal connection and meter tampering.

High priority:

- Caribbean Coast (Electricaribe)
- Nariño (CEDENAR)
- Chocó (DISPAC)
- Cartago (Emcartago)
- Casanare (Enerca)
- Caquetá (Electrocaquetá)



Region Prioritisation:

Alternative focus could be on retail competition

One of the key objectives of the AMI network is to improve retail competition, therefore it may make sense to focus the installation on the regions with uncompetitive energy markets.

How should the procurement be managed?

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- **Recommendations:**
  - The final choice on equipment and suppliers to use should be left to the local DNO.
  - Recommend use of local suppliers where available to support community engagement and facilitate a more efficient installation.
  - Cooperation between utilities should be encouraged for purchasing equipment to utilise power purchasing.
- **Variables to consider:**
  - Technology penetration.
  - Cost per meter.
  - Preference for local installers.
  - Availability and realistic time expectations.

Needs to be in line with Colombian Governmental policy

- **Procurement procedure:**

Request for information → Request for Proposal → Contract Award → Contract Management

Risks to be addressed

Currency

- **Issue**: Fluctuations in the exchange rate could impact the roll-out cost if Colombia opts for a foreign technology.
- **Solution**: Tender for a smart meter manufacturer to produce the equipment locally.

Political

- **Issue:** A change in political situation could cause disruption to the roll-out strategy, another political party may decide to withdraw the roll-out or choose a different technology option
- **Solution:** Difficult to estimate how a political party will address. Strong evidence of the roll-out should gain support from other a variety of government and private sector stakeholders.

Technical

- **Issue**: The pace of economic development accelerates and there is greater penetration of new technologies, e.g. EV's which require a higher functionality system.
- **Solution:** If there are sufficient demand and supply changes we would recommend integrating energy storage into the network.

Financial

- **Issue:** Investment for the smart meters does not materialise.
- **Solution:** Government backed finance or bonds could be issued for the smart meter project.

Conclusions:

- An AMI system would **reduce electricity losses and improve competition between suppliers.**
- **Interoperability** would be facilitated through **a single national requirement on functionality of an AMI system**.
- Our recommendation **would be for an organisation to be established to manage and control consumer data.**
- **Distributed Network Operators (DNO) to lead roll-out implementation:**
  - Roll-out to be led by regional DNO
  - DNOs to procure together where practical to obtain a discount and to achieve economies of scale for meter manufacturers
- **Proven technology option:**
  - PLC likely to be suitable communications technology for most regions, RF would be a good alternative for more sparsely populated regions
  - Meters to only monitor electricity, not sufficient need for gas/water
  - Not sufficient need for an in-home display considering the cost

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Detailed country analysis

- Evidence base for the main international country analysis
  - UK
  - Sweden
  - Italy
  - California
  - Brazil

UK: Additional details

Evidence base

UK Experience: Policy & Regulation

Meters:

The utilities were given the freedom to choose the suppliers for the meter and in-home display equipment through their own procurement process. However the level of functionality was defined by the UK government in two evolutions SMETS1 (initial meter) and SMETS2 (later meter with additional capabilities). All smart meters in the UK have to meet the CESG commercial product standard.

Smart Energy Code:

The Smart Energy Code (SEC) is a multi-Party agreement which defines the rights and obligations of energy suppliers, network operators and other relevant parties involved in the end to end management of smart metering in Great Britain.

Existing smart meters:

In the UK, some utilities chose to commence a smart meter roll-out prior to the government mandating a requirement on smart meters. The meters that do not meet the new regulatory requirements will need to be scrapped prior to 2020.

Source: Carbon Trust Analysis

UK Experience: Network and Meter functionality

Meter functionality

In order to ensure that the smart meters installed in people's homes meet certain standards and can be switched from one energy supplier to another, they will have to conform to DECC's Smart Metering Equipment Technical Specifications, known as SMETS2, which was developed in consultation with both network and retail utilities.

Dual meter functionality:

The UK opted to install an AMI system that monitors both electricity and gas consumption, with the electricity meter receiving data from the gas meter.

Visibility of energy consumption:

UK opted for an in-home display for every household to support consumers with analysing their energy consumption data. Not every household is required to have one, but they must be provided one by request.

Source: Carbon Trust Analysis

UK Experience: Implementation

Installation procedures:

No defined roll-out process, installation is driven by demand, therefore one installation engineer may visit one location multiple times. This is partly because the UK technology is based on cellular and long range radio communication. However, financial incentives are offered to utilities that install the AMI system on schedule.

Roll-out procedure:

UK opted for a foundation phase (2 years) to test systems and a full roll-out is estimated to last 5 years, although this is widely believed to be behind schedule due to a shortage of installers. **The UK opted for a retail utility-led approach which has also delayed the roll out as retail utilities did not have electricians available to fit the meters and their customers are geographically dispersed.**

Meter transferability:

The UK has not defined a set procedure for the transfer of ownership of a smart meter from one supplier to another when a consumer decides to switch supplier, although all meters are interoperable.

Code of practice:

Code of practice developed to ensure that consumers receive an appropriate standard of service during the installation procedure, are treated fairly and transparently, and understand how they can use their smart metering equipment to improve the way in which they use energy. The code prohibits installers from selling on further energy services during the installation.

Source: Carbon Trust Analysis

UK Experience: Communications Technology

Cellular radio technology for Central and Southern UK:

This enabled a high functionality and reliable system that integrated into existing infrastructure. In locations with insufficient network coverage it been more cost effective to use Long Range Radio Wave Communications. However, for 0.75% of the Southern UK a communication solution has yet to be identified.

Long Range Radio Communications for Northern England and Scotland:

The system for the Northern UK and Scotland is based on a US long range radio wave communication system that is better suited to areas with poor cellular network coverage.

Source: Carbon Trust Analysis

UK Experience: Data Management

Data Accessibility:

The DCC was competitively procured to manage the data and communications network to connect smart meters to the business systems of energy suppliers, network operators and other authorised service users of the network.

Data Operability:

Regulations in force to enable customers to switch energy suppliers with no financial penalties within 24 hours.

Cyber security:

The Government Communications Head Quarters (GCHQ) are supporting on the technical system design of the new system to ensure that suitable security exists on the meter and the communication system.

Source: Carbon Trust Analysis

UK Experience: Stakeholder engagement

Smart energy GB:

The aim of Smart Energy GB is to help everyone in Great Britain understand smart meters, the national rollout and how to use their new meters to reduce gas and electricity consumption. The organisation is independent from government and is non-profit.

Smart Grid Forum:

The UK Smart Grid Forum Portal has been established as a means to provide a hub for smart grid learning and information for industry, government and other key stakeholders.

Behaviour change:

In the UK visibility of energy consumption and cost of consumption over a half hourly period is provided to encourage consumers to reduce energy consumption.

UK Experience: Systems benefit

Synergies with other infrastructure:

The UK roll-out has combined electricity and gas together to exploit economies of scale. There is a smaller benefit in installing a smart meter for gas, as the price is not subject to the same volume of variation during the day. However, investment in other infrastructure such as the cellular network helps to support other industries.

Distributed generation connectivity:

In the UK households with intermittent renewable energy devices have recognised considerable benefits with being on a smart meter as the smart meter can track both energy consumption and the proportion of energy exported.

Source: Carbon Trust Analysis

Key lessons from the UK roll-out:

Observation	Lesson to be learned and recommendation for Colombia:
Policy & Regulation: In the UK two evolutions of meter standards have been released, SMETS1 (Foundation) and SMETS2 (Mass roll-out). This is warranted as the UK has opted for an unproven technology option, and the initial phase has allowed suppliers to test out the systems. A drawback is some suppliers are waiting for SMETS2 before rolling out smart meters.	Sufficient planning needs to be undertaken to specify an appropriate metering standard. The meter standard should be defined prior to the roll-out and that the procurement cycle should favour proven technologies.
Network and meter functionality: Suppliers have opted to roll-out smart meters at different stages and have chosen different smart meter equipment manufactures. If a consumer switches supplier, there is no guarantee their existing smart meter will be supported, it may be removed or dumbed down to act as a standard meter.	The cost will not be specifically applied to the consumer, the wider energy industry is expected to fund this, resulting in serious inefficiencies. Therefore the ownership of the meter should be with the distribution network operator rather than the electricity supplier. Currently the meter ownership is with the consumer. In addition, financial incentives should be offered to companies who install the AMI equipment on time.
Communication technology: The technology option has been divided up by two different regions in the UK (North and South) to ensure that all households can be met at a suitable economic cost.	Efficiencies can be realised by dividing up the roll-out by geography so Colombia should divide the technology option by regions. PLC technology would be suitable in urban areas and for more rural regions an RF network would be suitable. More information can be found in the rollout map found later in this pack.
Data management: The data communications company has successfully been established to support the facilitation of data transfer between the customer and the grid.	The UK data communications company manages the control of the data through the network, and would be a good example of an organisation in Colombia to replicate. An issue that will need to be overcome is how to define who can be authorised to access the energy data. Consideration needs to be taken for the consumer and the cost of accessing the data.
Data operability: Smart meters should constitute a more competitive energy market, if the systems are not switchable between suppliers this is going to impede competition.	Regulations need to be in place to ensure a customer can switch suppliers once a smart meter has been installed.
Implementation: Installation code of practice developed to ensure suitable standard of care is given throughout the installation.	Replication and adaptation of the UK code of practice should be implemented for Colombia.
Stakeholder engagement: Consumer engagement organisations have actively pushed the smart meter agenda across a range of stakeholders, helping to facilitate the roll-out.	The UK consumer engagement examples should be closely replicated in Colombia.

Source: Carbon Trust Analysis

Further observations from the UK

Theme	Observation
Installation	• **Installation procedure:** an installer is given up to two hours to install a meter, on average a **meter installer could install 2-3 meters per day**. • In rural areas this may be lower due to the time required travelling which augments the need to have geographically based roll-out to minimise costs. • **Social considerations:** when an installers visits the home this is a potential invasion of privacy. Particular care needs to be taken with those suffering from illness and the elderly. • **Installer training takes 6 months, 3 months for each fuel**. In the UK the training has been undertaken by the utility if they have the facility.
Marketing and outreach	• Significant investment has been made in convincing consumers and energy companies on the benefits of the roll-out. **British Gas (major UK utility) has recognised a 53% improvement in satisfaction and SSE have noticed similar level of improvement in consumer satisfaction**. • **Energy saving:** Smart Energy GB estimates that 80% of adults who have installed a smart meter have taken at least one action to reduce energy use.
Demographics	• **Over 65's and consumers with fewer qualifications have been found to be less likely to opt into the smart meter program.** Therefore communications should vary dependent on specific demographics. • **Rented properties:** Considerations need to be taken for landlords, for tenanted properties they need to be involved in the process of installing the meter. In the UK some landlords blocked tenants from installing a meter. A recommendation could be for the meter to be installed during a void period. • **(Dis) Connection:** To minimise consumer debt and unoccupied household energy consumption, suppliers can disconnect (and reconnect) customers remotely that have failed to pay their bill. However, this has the potential to cause serious harm or death to those consumers in poverty, particularly in winter months.
Technology	• **In-home displays (IHD):** higher smart meter recommendation rates for those with IHD's (81% recommend with an IHD compared to 67% without an IHD), making the case for some benefit received from an IHD. An application could gain similar benefit, but work would need to be done on promoting

Source: Carbon Trust Analysis

Relevance of the UK scheme to Colombia and the lessons that can be applied?

What should Colombia adopt from the UK roll-out?

- A **data communications company** should be established in Colombia to manage and secure data.
- A **customer engagement contact point** should be implemented to address concerns with both businesses and domestic customers as well as foster the promotion of the roll-out.
- **Defined training protocol for installers** to ensure a high standard of care during the installation.
- **An installation standard for the PLC / RF network should be introduced** to ensure the AMI network is of sufficient quality and consumers receive a good standard of care.

What should Colombia avoid?

- **Cellular communication technology option** would be expensive and the network coverage is not sufficiently establi**shed in Colombia as the UK. Therefore PLC or RF would be more suitable.**
- **Dual utility (i.e. gas and electricity) would not be required** for a Colombian roll-out.
- An **in-home display would be an unnecessary expense**, in the UK the roll-out is estimated to cost more than £200 per household, a significant proportion of Colombian GDP per capita. The in-home display could also be at risk of theft.
- The UK installation procedures has been driven in part by consumer demand, **if Colombia is to make PLC and RF technology cost effective the installation should be based on geographic area**.
- **Responsibility for the smart meter should not be with the utility, the distribution network operator should own and manage the smart meter.**

Sweden: Additional details

Evidence base

Sweden Experience: Policy & Regulation

Need for smart meters:

Smart meter roll-out driven by government regulation to bill based on monthly readings in 2003. Later in 2006 the government changed the requirement to hourly readings which made some meters installed prior to 2006 obsolete.

Decision on technology:

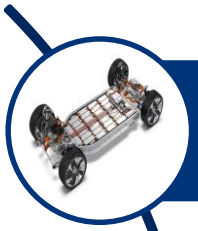
Utilities installed AMI systems in response to the government regulation on metering, therefore no set requirements on functionality or technology exist. Prior to installing the AMI networks, utilities ran pilot projects to test technologies and installation procedures to ensure the correct decision was made later in the roll-out.

Mixed network:

Lack of cohesion between utilities has resulted in multiple communication technologies being installed, this has increased the cost of the roll-out but has been a good platform to demonstrate which are the most effective technologies. No defined common functionality exists across the AMI systems installed.

Source: Carbon Trust Analysis

Sweden Experience: Implementation



Changing Energy Demands:

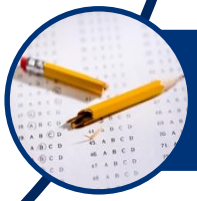
Energy demands have changed since the roll-out, including increased EV ownership and heat pumps.

Multiple Occupancy buildings:

Long payback period for those in apartment buildings as there is less scope to take part in behavioural changes that will net sufficient savings to offset the cost of the smart meter technology.

Roll-out procedure:

Vattenfall (a major Swedish utility) opted for a roll-out based on geography to ensure the best choice of technology and economies of scale. Variability experienced in the functionality of the meters, due to separate procurement cycles over 6 years of the roll-out.



Pilot phase of testing required:

In Sweden it has been estimated that it took 1-3 years to resolve all of the communication problems with individual meters.

Source: Carbon Trust Analysis

Sweden Experience: Technology

Communications Technology:

PLC system in Sweden has been found to be less reliable than GPRS (Cellular) communications, this is perhaps due to the higher latency and disturbances over the wires. However winter snow has impacted the maintenance schedule of an RF system.

Fault isolation:

The AMI system automatically detects faults and can isolate the part of the network with the fault. Customers are notified through web and SMS and the utilities can provide information on when they think power should be restored.

Faulty meters:

Early meters had to be replaced due to faults, this was partly due to the early stage of the smart meter technology.

Technology Obsolete:

Sweden's decision to act as a pioneer in rolling out smart meters has resulted in some of the technology becoming outdated.

Source: (GEODE Working Group Smart Grids, 2013); (Engelen and Collins, 2010)

Sweden Experience: Asset Management

Ownership of meter and network:

The meter is owned by the distribution company and there is no need to change the meter when changing suppliers.

Packaged meter solutions:

Distribution network companies opted to purchase complete meter system solutions from meter manufacturers, including the software, communications infrastructure and the meter as well as the installation procedure. Many meter manufacturers could not deliver the service economically and filed for bankruptcy.

Procurement:

Smaller DSO's cooperated when purchasing smart meter technologies to increase their purchasing power.

Source: Carbon Trust Analysis

Key lessons from the Swedish roll-out?

Observation	Lesson to be learned and recommendation for Colombia:
Policy & regulation: Suitable preparation should be taken to prevent future regulation changes. In Sweden the government changed the meter requirement from monthly to hourly readings which resulted in the removal of some of the earlier stage meters. This has added considerable expense to the roll-out which ultimately will be placed onto the consumer.	Defining the communication technology or providing a standard should help to provide an industry wide AMI solution, preventing a mixture of technologies being installed.
Implementation: Sweden has recognised changing energy demands during the roll-out, there have been a greater number of EV's and heat pumps increasing the demand on the grid. In addition, some of the early meters failed, partly to smart meters being in the early stage of their development.	Colombia's energy demands are expected to change over the duration of the planned roll-out, thought needs to be taken as to how. The early stage meter failures should no longer be an issue considering that by the time of the roll-out there has been about 15 years of development in smart meter technology.
Technology: Some useful insight has been gathered from Sweden through the multiple communication options utilised. PLC has been found to be less reliable than other communication technologies. An additional benefit of the AMI system has been recognised through quickly identifying network outages. Technology becoming obsolete has been an issue for Sweden.	Some of the problems posed to a PLC system in Sweden were in part due to the material that the PLC system is made from. These issues are therefore less relevant for Colombia. The ability to visibly determine where network outages occur are going to support Colombia's need to reduce power outage times. An innovative solution can be learnt from Sweden by encouraging cooperatives for smaller DNOs to come together to purchase metering equipment.
Asset management: To minimise risk many of the Swedish distribution network companies opted to purchase a full AMI solution from an external company, whom would provide ever	Sufficient preparation required to set up and establish meter and related equipment providers within Colombia. As AMI technology has developed it is expected the costs and risks associated with the technology have reduced.

Source: Carbon Trust Analysis

Further Observations Sweden

Theme	Observation
Finance	• **Variable tariff structure**: Only 0.17% of energy users decided to opt into the variable tariff structure.
Marketing and outreach	• **Customer satisfaction:** Noticeable increase in satisfaction with those customers that have installed a smart meter.
Retail Competition	• **Interoperability:** No significant changes in the number of consumers switching suppliers, but now consumers are no longer fixed to switching energy suppliers at certain dates in the month. A switch can be made within 24 hours
Installation	• **No training licence required:** To train sufficient personnel a license was avoided due to the processing time. A particular training programme was also introduced that unskilled personnel could unroll on, that included both technical and non-technical soft skills. • **Local contractors:** A local organisation is going to have a greater knowledge of the local conditions and therefore should be able to install the equipment more effectively. Sweden opted to use local installers where possible which also contributed to greater consumer acceptance of the meters.
Implementation	• **Pilot phase of testing required:** In Sweden it has been estimated that it took 1-3 years to resolve all of the communication problems with individual meters.
Intermittent Renewable Energy Sources	• **Microgeneration has become easier to install:** Similar to the UK benefits have been recognised of installing microgeneration sources in homes.
Energy Efficiency	• **Negligible energy demand from meter:** The energy consumed by the meter has been recognised in Sweden although the benefit of the device should sufficiently outweigh the meter energy consumption.

Source: Carbon Trust Analysis

Relevance of the Sweden roll-out to Colombia and the lessons that can be applied?

- **What should Colombia adopt from the Sweden roll-out?**
  - Meter ownership to fall with the DNO, to minimise problems with switching energy suppliers and avoid removal of functional meters.
  - Geographic based roll-out to achieve economies of scale.
  - The tender procedure for the smart meter and communications should favour a proven technology. If a new technology is chosen a contingency budget should be included for issues with the network.
  - Fault isolation procedure – inform consumers of a fault via SMS or the web and isolate the grid to the particular location of the fault.
  - Collusion between smaller operators on purchasing metering equipment to realise cost savings.
- **What should Colombia avoid?**
  - A change in policy and undefined industry standards for the smart meter and communication system can lead to serious inefficiencies and expensive changes to the roll-out. Recommendable to **create a homogenous standard.**

Italy: Additional details

Evidence base

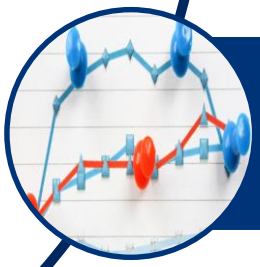
Italy Experience: Policy & regulation

Roll-out procedure:

Initially the roll-out was driven by the utility Enel. From 2006 onwards the Italian government mandated that all of the population should be obligated to switchover to a smart meter.

Cost recovery:

Metered tariff to recover the €70 cost from the consumer. The tariff was only applied once the meter has been installed.



Specific tariffs for consumers and for industry:

Tariffs varied for different consumer groups, two tariffs per day were introduced for domestic customers and three tariffs were introduced for commercial organisations. The tariffs lead to a small reduction of 1% of demand during peak consumption, this was partially due to the 'on' and 'off' peak rates not being sufficiently different and also partly attributed to Solar PV reducing the cost of energy.

Source: Carbon Trust Analysis

Italy Experience: Implementation

Cyber security:

Authentication of data established between the meter and the concentrator, no encryption required.

Meter Standards:

'Meters and More' established by Enel and Endesa to establish a common communication protocol for smart meters across Europe. This has since attracted funding from the European Commission.

System Design Completed by ENEL:

Major Italian utility set out the design of the metering technology and specifications. The equipment was manufactured by contract manufacturers.

Source: Carbon Trust Analysis

Italy Experience: Technology

Grid Management:

Enel can now see where issues are on the electricity grid and therefore can be quicker to respond to issues that arise.

Reliability of Communication System:

PLC system found to be less reliable than copper or fibre connections, in the second roll-out Italy is going to replace PLC and GSM communication lines to copper and fibre optic. This should help to reduce maintenance costs. Limited data transfer capability has also been noted.

Integration of other utilities:

The second stage of the roll-out is likely to include the integration of gas and other metering systems within the smart meter. This can lead to time, operational and cost efficiencies.

Source: Carbon Trust Analysis

Italy Experience: Stakeholder engagement

Innovative services:
Enel the Italian utility has developed a smart software solution called 'Smart info' to engage consumers on their energy usage. This is in place of offering an in-home display, consumers can access the data through a website and an application on smartphones and tablets.

Remote curtailment:
For those that cannot cover their energy bills, their power output is reduced to 10%. This ensures sufficient disruption is caused to those 'non-payers' but they should not fall into poverty. They can be reconnected to the grid quickly and at a minimal cost once the debt has been repaid.

Source: Carbon Trust Analysis

Key lessons from the Italian roll-out?

Observation	Lesson to be learned and recommendation for Colombia:
Policy & regulation: Italy was an early country to adopt smart meter technology and introduced legislation to mandate the roll-out in 2006. The variable tariffs based on consumer and industry tariffs allow for greater influence on energy behaviour.	Italy and Colombia have similar needs for an AMI system that stem from needing to reduce non-technical losses and improve network planning, therefore the initial installation of meters was undertaken by the national utility Enel. The tariff structure did not sufficiently reduce energy demand but this was partly due to a reduction in the overall energy price.
Implementation: 'Meters and more standard' established in Italy to encourage unanimous meter compatibility. As the system design was undertaken by one utility less complications existed on the national roll-out.	The meters and more standard could be introduced in Colombia, however this recommendation may lead to this report favouring a particular meter supplier.
Technology: Similar conclusions to Sweden on the PLC technology reliability being problematic. Benefits have been seen from adding copper and fibre optic cables.	There is a sufficient case to model in the cost of fibre optic and copper based alternative to a PLC system for Colombia.
Stakeholder engagement: The innovative service offering is a strong example of offering a more cost effective solution than a home display. Also the ability to reduce the power supply to a certain threshold of the supply is an important those	Providing the option for a web based solution for Colombia could be hugely beneficial to drive down costs of the roll-out, whilst also allowing innovation in the market place.

Source: Carbon Trust Analysis

Source: Carbon Trust Analysis

Further Observations Italy

Theme	Observation

Technicalities	• **Considerable energy recovered from the system due to**:
	  • Replacement of worn out meters
	  • Reduction in thefts and tampering
	  • Correction of customer records
	  • Elimination of customer estimation
	
	• **Network improvements:** Noticeable improvements in quality of service, from 128 minutes of disruption in 2001 to 42 minutes of disruption in 2011.
	• Cost of service per customer decreased from €80 to €48 per year.

Marketing and outreach	• **Consumer engagement:** DNO recorded fewer consumer complaints and additional queries on how to conserve energy
Illegal connections	• **Total number of customers:** The roll-out lead to an additional 500,000 customers.
Promotion of intermittent renewables	• **Incentives:** Attractive financial incentives were brought in for renewables which lead to a surplus of wind and PV energy in the south which was sold to DNOs in the north.

Source: Carbon Trust Analysis

Relevance of the Italian scheme to Colombia and the lessons that can be applied?

- **What should Colombia adopt from the Italian roll-out?**
  - In the initial roll-out Italy had similar issues to overcome (reduction of non-technical losses), and a PLC system was deemed the most suitable solution.
  - Endesa a major Colombian utility is a subsidiary of Enel, whom rolled out the Italian and Spanish AMI programmes. Potentially the knowledge and technology can be transferred to Colombia for minimal cost.
- **What should Colombia avoid?**
  - Unnecessary duplication of infrastructure, Italy in the second roll-out has installed multiple fibre optic networks for AMI systems and telecoms networks, causing additional costs and disruption.
  - **Italy has come to a similar conclusion to Sweden that the PLC system can be unreliable, and the cabling should either be fibre optic or copper**

California: Additional details

Evidence base

California Experience: Policy & Regulation

Regulation:

California Public Utility Commission (CPUC) announced that all electricity customers should have smart meters in 2003. Later in 2006 the CPUC mandated the roll-out to be lead by the utilities.

Data Protection:

Rules to protect the privacy and security of customer data and policy to govern access to customer usage data by customers and by authorized third-parties as ordered by SB 147

Smart Meter Opt-out Programme:

Consumers have the option to opt-out of a smart meter at a specified cost. To achieve the maximum utility from a smart grid system you would want to achieve as close as possible to 100% market penetration of smart meters.

Governed State Law on Data Operability:

An electrical corporation shall not share, disclose, or otherwise make accessible to any third-party a customer's electrical consumption meter data without the consent of the customer.

Source: Carbon Trust Analysis

California Experience: Implementation

Installation Procedure:

To minimise inconvenience to customers the smart meter installation was scheduled and if the first attempt was inconvenient, the customer was given an option to reschedule at their convenience.

Utilities were required to install a system that:

Allowed for fast outage detection and restoration of service, customer control over energy use with time based tariffs, reduces the environmental impact, greater privacy and above all allows the consumer to make an informed decision on energy usage.

Impact on Labour Markets:

Remote reading reduced the need for meter readers and would therefore have a subsequent impact on the labour market, Californian utilities worked with the utilities to ensure that remote meter readers could become an installer or another role within the organisation.

Innovative Services:

The US Department of Energy sponsored a competition to design an energy app that consumers could use to view their energy consumption. This allowed innovation and brought in ideas from outside the energy industry, and ultimately helped to improve consumer engagement.

Source: Carbon Trust Analysis

California Experience: Technology

Proven Technology:

Consumer distrust over smart meter over the accuracy of the billing and the expense of billing warranted the need to install a proven technology. In the pilot phase of the roll-out concern was warranted that an unreliable AMI system could cause sufficient negative publicity that could lead to the reversal of the roll-out procedure.

Green Button Initiative:

The Green Button initiative gives utility customers easy access to their electricity usage data. This data is provided as a text file in a format that is standard across multiple utilities. This data file can then be shared with third party developers who can provide valuable context, analysis, and other functions based on that usage data.

Health impacts of RF:

Concerns around the metering technology health effects have been explored in the US, the radiation exposed from an RF network is lower than that of a cellular phone network.

Source: Carbon Trust Analysis

Key lessons from the California roll-out?

Observation	Lesson to be learned and recommendation for Colombia:
Policy & regulation: Data protection, health and an opt out programme have been important considerations for Californian policy makers. The opt out policy is potentially counter productive.	California is a good example of a regional based roll-out, and there have been several local state policies to aid the roll-out procedure. It would be unsuitable to recommend the opt-out programme for Colombia, as this would severely limit the ability for active network management.
Implementation: Excellent work was undertaken in California to reassign those in meter reading jobs to other vacancies. By allowing the customer to schedule the installation of the equipment should improve customer engagement and acceptance. However, this could impact on efficiencies for installing equipment, particularly for those in rural locations.	Colombia should replicate the programme to re-train those jobs that are threatened by a smart meter roll-out. Where available the installation procedure should be driven by customer preference whilst considering optimal efficiency for the number of homes installed. More leniency could be given to those homes in urban and sub-urban areas on installation preferences.
Technology: California has been successful with enabling innovative services in the smart meter market by opening the technology services up to those that are not within the energy industry. The green button initiative allows users to easily share their data to receive a more effective tariff, and it allows them to take control of their energy usage. The health impacts of RF networks have been found to be negligible so far.	Allowing and enabling innovation in the market place can help to improve the engagement and cost effectiveness of the roll-out. Colombia does not have the same level of innovation based company as California, but where available solutions for issues throughout the roll-out could be tendered to the local market. Consumers should have access to historical consumption data through an online based tool.

Source: Carbon Trust Analysis

Relevance of the Californian roll-out to Colombia and the lessons that can be applied?

- **What should Colombia adopt from the Californian roll-out?**
  - Allow those outside of the energy industry to provide solutions to the roll-out to encourage innovation.
  - To foster consumer engagement provide the consumer with the opportunity to schedule the meter installation.
  - Work with the unions to ensure minimum disruption to those jobs may be displaced by the roll-out.

- **What should Colombia avoid?**
  - Opt-out programme should be avoided. Consumers in Colombia may see benefit in opting out of a smart meter and then tampering with the electricity supply.

Brazil: Additional details

Evidence base

Lessons learnt from Brazil, common issues to overcome

- **Regional based roll-out, driven mainly by utilities.**
- **Inova Energia** provides a series of subsidies and other incentives to assist Brazilian companies and technology institutes to develop and commercialize innovative technologies for the power sector, including smart grids. Through the Inova Energia programme (coordinated by ANEEL, the Brazilian development bank - BNDES, and the federal government's funder of studies and projects - FINEP) the government plans to invest more than R$4.5 billion in smart grid related R&D. Much of this work includes AMI and distribution automation, as well as communication systems, IT and distributed generation projects. This fund should help support the growth of the smart grid market in Brazil and attract additional investment into the area as projects become commercialised.
- **R&D Targets for power generation, distribution and network companies –** commitments usually resolve in investment in smart grid infrastructure.
- **BNDES accredited manufacturers and equipment list –** favourable interest rates to set up companies with specific categories.

Source: Carbon Trust Analysis

Relevance of the Brazilian roll-outs to Colombia and the lessons that can be applied?

- **What should Colombia adopt from the Brazilian roll-outs?**
  - Innovation based investment targets for utilities to encourage smart grid investment and development.
  - An accredited list of smart meter equipment manufacturers.

- **What should Colombia avoid?**
  - Lack of clarity on roll-out could lead to multiple inoperable systems being introduced in different regions. In Brazil's case there is a risk if a national roll-out goes ahead at a later date that the AMI equipment previously installed will need to be removed if they do not meet the new standards.
  - Lack of economies of scale and issues with potential interoperability.

Additional details on Colombia initiatives

Evidence base

Electric Vehicle Penetration

- **AMI Network potential:** Smart meters can be used to track and identify power demands.
- **Impact on AMI Network:** We do not believe that the electric vehicle market in Colombia will have sufficient impact on the AMI system until after 2025. Electric vehicle energy demands are minor from a national grid perspective, but the impact can have sufficient constraints on particular parts of the grid when a charging station is installed.

In California utilities request customers to inform them on when they purchase an electric vehicle. If issues arise during the roll-out Colombia could introduce a similar rule.