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Report on ICT requirements and recommendations

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## Executive summary

This report describes in detail the ICT requirements and makes recommendations for the defined processes of WP4.

Firstly, a table is presented with a detailed description of the quantitative review of the technologies that have been studied in the D4.1 and D4.2 in order to define then the ICT requirements for the defined communication processes. The main features included in the table are the range, the frequency and throughput.

Then, it is presented the main features for evaluation criteria that allow the evaluation of different communication technologies. The ICT requirements for the electric vehicle applications will be evaluated along this document according to the attributes of throughput, data delivery time (latency), quality of service (reliability and availability), and security aspects.

After that, it is presented the evaluation of the ICT requirements where the ICT requirements are described that are needed for each process of identification, of power exchange and of billing, using the features described in the previous section.

Finally, it is presented a description of the communication method recommendations. These recommendations are defined for each communication path: Customer Identification communications, Electric Vehicle to Charging Pole communications and upstream communications of the Charging Pole. The ICT recommendations are:

- **Customer ID communications:** In all scenario worlds, RFID is a suitable and cost-effective technology when the ID process is needed. These communications will improve to NFC, which should be most adequate solution in advanced scenario world when this technology becomes more consolidated. The use of Smart Cards is an alternative that should be taken into account when more complex features are required due to its higher costs in comparison with RFID.
- **Electric Vehicle to Charging Pole communications:** CAN-bus should be an appropriate technology in this process, as it is already used in automation industry. Also PLC and RS-485 are favourable methods, but they need a higher investment and they should be used in future scenario worlds.
- **Upstream communications of the Charging Pole:** In this communication path, several technologies can be installed such as Ethernet, GPRS, UMTS, Wi-MAX, etc. The technology and architecture of the communication path used are highly related to the location or environment of the charging pole.
  - o **Dense areas:** In urban areas with a high density of Charging Poles, a Concentrator device should be installed between Charging Poles and the upstream stakeholders. A combination of PLC for the last mile between the Concentrator and the Charging Poles, and wireless communications (such as GPRS or UMTS) or using any other already existing infrastructure (Ethernet, FTTH or PSTN copper wires) for the upstream communications of the Concentrator could be the most recommended solution.
  - o **Rural areas:** In rural areas where the Charging Poles are more dispersed, the use of concentrators to aggregate data from several poles is not needed. In these situations, the communication between the information system and the Charging Pole is recommended to be performed directly via existing PSTN copper networks or GSM networks.

Regarding the implementation of these upstream communications, it makes economic and technical sense for the Aggregator/Retailer to use ISPs telecommunications services to reach the concentrators.

The ISPs structure should be able to provide a cheaper and better service, than if the Aggregator/retailer would do it itself. In some situations in the advanced world, the Aggregator should also try to take advantage of an existing internet connection to the customer and use it as the connection path. More so it is the case, if specialized ISPs are used, as it is the case in DSOs' Smart grids, as a platform for reaching the customer location. DSOs' smart grids are supported on a communications platform, which can be self-operated or in its turn subcontracted to an ISP.

Finally, the cost of ICT technologies is assessed by considering both the infrastructure and operation cost. Infrastructure cost includes network infrastructure, smart meter and other costs (as management and deployment). Infrastructure costs are obtained through a benchmarking of different projects that deal with smart metering and electric vehicle deployment. Operation cost considers the access to a broadband communication network and is assessed through different transmission rates. The data obtained from these sources have permitted to estimate the range of costs for ICT infrastructure needed for the evaluation of each scenario world.

# 1 Introduction

This document belongs to the Task 3 of WP4, which is a continuation of Task 1 (deliverable D4.1) and Task 2 (deliverable D4.2) of the same WP4. These previous deliverables have described the report on ID and charging architecture and recommendations, and the report on billing and stakeholder's architecture and ICTs recommendations, respectively. Then, this deliverable basically defines and summarises the ICT requirements and makes recommendations for the defined processes of WP4. As it is known, this WP4 has the overall aim to get functional recommendations for the global ICT solutions for the electric vehicles infrastructure. Besides, this deliverable is the last one of WP4, so at the end of this document, the objectives of WP4 will be accomplished.

As has been studied, there are several technologies with different features and applications. Hence, there are several options available to implement the communications of each process. Obviously, it is desirable to choose the best technology for each communication process and this will be discussed in the following sections using the steps below:

- Review of different available technologies with a summary of their main features.
- Description of the main features that allow the evaluation of different communication technologies.
- Description of the ICT requirements needed for each process, using the features described previously. The evaluated processes will be: ID for electric vehicles and the electric vehicle supply equipment processes, power exchange process and billing process.
- Study and recommendations of the best technology for each communication process.
- Assessment of the cost of the recommended ICT technologies for each scenario world.

Moreover, the evaluation criteria of ICT requirements will be studied for each communication process (ID of the user and the EV processes, power exchange process and billing process) and for each of the possible scenario worlds (conservative, pragmatic and advanced).

## 2 Review of technologies

As have been studied in deliverables D4.1 and D4.2, there are different communication methods available to perform the different communication processes involved with the infrastructure of electric vehicles. These technologies were deeply described and evaluated in D4.1. This section summarizes a quantitative review of these technologies in order to define then the ICT requirements for the defined communication processes.

In this way, Table 1 includes a brief description, a summary of characteristic attributes and the standards in which are based each of these communication methods. These cited attributes are range, frequency and throughput, which are briefly described below:

- Range: transmission distance of the communications
- Frequency: the used frequencies during the communications
- Throughput: the amount of data that can be carried from one point to another in a fixed amount of time (usually a second). This kind of throughput is usually expressed in bits of data per second (bps).

These attributes, and other characteristics studied in D4.1, will determine if they are suitable for each of the defined communication processes. Some characteristics of these technologies make them only suitable for one specific process. However, some of these communication methods can be used in more than one application.

Table 1: Overview of technologies

Communication method	Description	Features			Standards
		Throughput	Used frequencies	Range	
<b>RS-485, [1]</b>	A standard for the electrical characteristics used in a linear network	100 kbps, 34 Mbps	NAP	Up to 1,2 km, up to 10 m	TIA/EIA-485
<b>RFID, [2]</b>	A radio frequency technology primarily used for the identification.	106 to 848 kbps	13,56 MHz	< 10 m	IEC 14443, IEC 15693
<b>Smart Cards, [2]</b>	Card that includes an embedded integrated circuit chip that can be either a secure microcontroller or equivalent intelligence with internal memory.	NAP <sup>1</sup>	NAP	< 0,1 m	ISO/IEC 7816, ISO/IEC 14443
<b>Magnetic stripes, [2]</b>	Cards that contain a stripe made out of magnetic particles and capable of storing data.	NAP	NAP	0 m	ISO 8583, ISO/IEC 4909, ISO/IEC 7810, ...
<b>Near field communication (NFC), [3]</b>	A short-range wireless communication technology, that enables simple and safe two-way interactions between electronic devices	424 kbps	13,56 MHz	< 0,2 m	IEC 14443, ISO/IEC 18092
<b>CAN-bus, [4]</b>	A vehicle bus standard designed to allow devices to communicate within a vehicle without the need for a central computer.	1 Mbps, 125 kbps	NAP	< 40 m	ISO 11898-1
<b>Pilot signals (PWM)</b>	Pulse Width Modulation	NAP	< 100 kHz	NAV	SAE J1772
<b>ZigBee, [5]</b>	An open standard for a suite of communications protocols based on the IEEE 802,15,4 standard	250 kbps at 2,4GHz 40kbps at 915Mhz 20kbps at 868Mhz	2,4GHz (global) 915Mhz (Americas) 868Mhz (Europe)	10 to 75 m	EU EN300-220 , IEEE 802.15.4
<b>Bluetooth, [6]</b>	An open wireless protocol for short distance data exchange.	2,1 Mbps	2,4 – 2,5 GHz	100 m	NAP
<b>Power line communications (PLC), [7]</b>	A system whereby a modulated carrier signal is superimposed onto the standard electric wiring.	500 kbps – 1,5 Mbps	Utilities = 10-490 kHz Broadband = 1,6-80 MHz	>1 km	NAP
<b>Wi-Fi, [8]</b>	A set of standards (IEEE 802,11) for wireless local area network communications.	54 Mbps	2,4 GHz	50 - 250 m	IEEE 802.11
<b>Wi-MAX, [9]</b>	Worldwide Inter-operability for Microwave Access is a Wireless technology based on the IEEE 802.16 series standard	up to 70 Mbps	500 – 800 MHz, 2,3 GHz – 4,0 GHz, 5,0 – 5,8 GHz	50 km	IEEE 802.16
<b>ADSL</b>	A type of data transmission on digital subscriber lines, supported on copper pairs of telephone lines.	8 Mbps - 24 Mbps	10 kHz – 1,1 MHz	>2 km	ANSI T1.413 Issue 2
<b>FTTH [10]</b>	Fiber to the home is the concept of bringing fiber optic connection all the way to the inside of the customer's house.	2,5 Gbps - 1,2 Gbps	NAV <sup>2</sup>	NAV	IEEE 802.3
<b>GPRS, [11]</b>	General Packet Radio Service. A packet oriented mobile data service that extends the GSM.	from 56 to 114 kbps	900, 1800 MHz	up to 2km	GSM standard
<b>UMTS, [11]</b>	Universal Mobile Telecommunication System, also known as 3G or third generation mobile technology, is an evolution of existing 2G/GPRS	> 7,2 Mbps	850, 1900 and 2100 MHz	Up to 1,5 km	GSM standard

<sup>1</sup> NAP: not applicable to this technology<sup>2</sup> NAV: not available

### 3 Main features for evaluation criteria

The objective of this section is to describe the main features that allow the evaluation of different communication technologies. Before discussing the factors that affect each process, it is necessary to clarify the terminology.

The term feature can be used to define the individual measurable heuristic properties of the phenomena being observed. From this perspective, the description of main features can be qualitative and quantitative. On the other hand, the ICT requirements are the constraints, demands, needs or parameters that must be satisfied within certain process. In this way, this section is taking into account the some relevant features in order to define the requirements and the suitable ranges for each communication process.

The ICT requirements for the electric vehicle applications will be evaluated in this document according to the following attributes:

- **Throughput:**

The throughput is one of the most important factors that limits communications speeds. In communications, the transmission throughput speed is a measure of how many times the physical signal changes per second and is expressed as the baud rate. If each change represents the value of one bit, the baud rate is equal to the bit rate, which is expressed in bits per second (bps or bit/s). Then, the maximum data rate is always limited by the throughput of the link. Thus, the throughput represents the maximum frequency at which signal changes can be handled before attenuation degrades the message. As a signal tends to attenuate over distance, communications links may require repeaters placed at intervals along the link, to boost the signal level.

To determine the throughput that is needed for each process, first we will determine the size and frequency of messages that are communicated through the network and then we will use these numbers to calculate the minimum needed throughput of each type of message and process.

Due to difficulties in calculating the exact throughput required for each process, reference ranges can be determined to facilitate requirements evaluation. The reference ranges used for the requirement definitions in this document are:

- High = greater than 1 Mbps;
- Average = between 10 kbps and 1 Mbps;
- Low = lower than 10 kbps.

- **Data delivery time (Latency):**

Response time can be defined as the period it takes from the instant a command or request is initiated from one device to another device until the instant the receiving device respond to the command or request. It is also known as latency. It is needed to determine the minimum latency for each type of message and process (in seconds). The response time depends mainly on the transmission speed as well as the media access method.

Due to difficulties in calculating the exact latency required for each process, reference ranges can be determined to facilitate requirements evaluation. The representative reference ranges considered in this document are:

- High = less than 500 ms;
- Average = between 0.5 and 5 s;
- Low = greater than 5 s.

- **Quality of Service (Reliability and availability):**

Reliability is the ability of a system or equipment to perform its intended functions under specified conditions for a specified period of time. The reliability of the communication system can be quantified in terms of Bit Error Rate (BER). Error rate is related to factors such as signal-to-noise ratio, noise and interference. Generally, there is a compromise between transmission speed and the allowable error rate, depending on the type of application. Ordinarily, it's interesting that the process has low error rate and it is normally designed for maximum reliability of data transmission, which means that it will be comparatively slow in data transmission terms. Then, as data transmission rates increases, the error rate increases as well, until there is a point at which the error rate becomes excessive.

Due to difficulties in calculating the exact reliability required for each process, reference ranges can be determined to facilitate requirements evaluation. The selected reference ranges are:

- High = No errors allowed (information loss smaller than 0,01%);
- Average = Limited errors allowed (between 0,01% and 0,1%);
- Low = Some errors allowed (greater than 0,1%).

Availability of a unit or a system is the ability to perform its required function at any given moment. Availability is also the proportion of time that a system is in a functioning condition (%). In a more general meaning, to evaluate the availability requirements of a communication system, it can be translated as the necessity that a determined data has to be transmitted in a specified instant.

Due to difficulties in calculating the exact availability required for each process, reference ranges can be determined to facilitate requirements evaluation. The reference ranges used for availability requirements are:

- High = No data can wait (greater than 99,9%);
- Average = Some data can wait for a limited time (between 90% and 99,9%);
- Low = All data can wait until link available (lower than 90%).

- **Security aspects:**

In the infrastructure of the electric vehicles and their communications processes, the information security is an important asset. These processes have many customers storing sensible information which must be protected. For that reason, it is important to define the necessary security aspects in order to know the level of security required of each communication process. Security aspects include characteristics like difficulty of external access, confidentiality and integrity of data, or system vulnerability. To increase the security of a communication system some improvements can be used like codes, modulations, keys or encryptions.

Due to difficulties in calculating the exact security required for each process, reference ranges can be determined to facilitate requirements evaluation. For the description of the requirements, these ranges are divided into the following levels:

- High = Data is highly confidential and all possible measures have to be taken that no one can access the data;
- Average = Data is not confidential, but manipulation has to be prevented by all means, as any change in data is critical to the system performance;
- Low = Data is not confidential, and any change in data is not critical to the system performance.

## 4 Evaluation of the ICT requirements

In this chapter, the ICT requirements needed for each process are described using the features described in the previous section.

### *4.1 ICT requirements for the ID and recommendations for electric vehicles and the electric vehicle supply equipment processes*

In the other deliverables, D4.1 and D4.2, of this working package a number of applications of ICT-systems related to all aspects of power system operation have been identified. The applications differ regarding their process-complexity and data and communication intensity. In previous sections of D4.3, a classification scheme of a number of information and communication technology attributes has been given. In this section the ICT-requirements for identification are evaluated as to the EV vs. EV supply equipment (EVSE) related processes.

EV identification and specification of the attributes and current status of electric vehicle processes to various stakeholders in the outside world in a reliable way is of prime importance to make EV applications and business models possible. Electric vehicles more or less become a mobile electricity storage component of the energy and specifically the electricity grid. This has consequences for management of the physical infrastructure as well as for commercial operations of these electricity storage resources. Also location independent information like state-of-charge and planned driving schedules may be important for system optimization for connected vehicles or even not-connected vehicles considered as mobile Smart Grid components in ‘advanced world’ scenarios.

However, there are some situations and business models in which the user identification process could not be necessary. For instance, if the charge is made at home, at work or at a public parking place (using a credit or prepaid card), the customer identification could not be mandatory. All these situations are not exclusive of any scenario, so both the necessity and the absence of the identification process need to be considered in all the scenario worlds.

Current physical charging infrastructure models already in-place include:

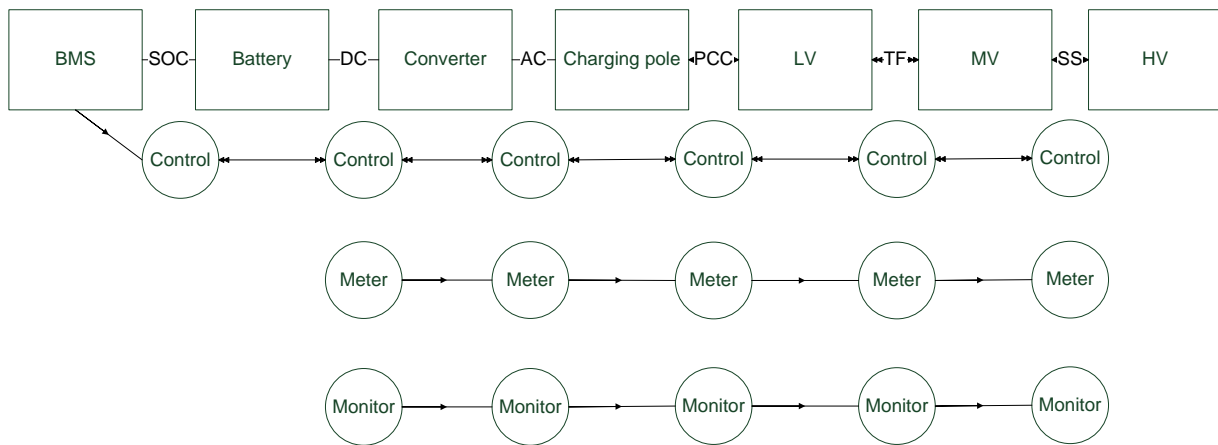
- Battery pack exchange. The simplest partitioning results, if the battery charging process is centralized in dedicated high-volume charging nodes as in the BetterPlace business scenario ([www.betterplace.com](http://www.betterplace.com)). For commercial operation aggregated electricity consumption profiles can be built-up quickly. These profiles may be optimized for real-time tariffs and network constraints. The charging unit will be part of the stationary grid.
- Petrol filling station model. As these stations will only serve high volumes in fast charging mode, the converter will be part of the stationary grid.
- Parking place/office building (fast) charging model. Here the converter can be stationary again or inside the EV.
- Home charging. The traditional in-home grid and sockets are not designed to serve power and load duration of EV-type loads. Therefore, new Charging Poles need to be offered to early adopters of EVs.

Segmentation and scoping of units in the EV to EVSE process as to locality and mobility of information streams helps in categorizing the requirements regarding information and communication aspects.

In

Figure 1, schematically, the physical components and possible processes are depicted that might occur in the mobile smart grids components. Physical entities are contained in rectangles and circles contain processes. In a linked manner, the following entities appear:

- The battery management system. The battery management system guards the state-of-charge and the state-of health. Part of the constraints on charging is defined by the battery manufacturer via the Battery Management System (BMS).
- The battery. Currently there are business models in which cars have fixed batteries that are exchanged when their battery life time has ended. In other business models, batteries are exchanged as a whole and charged separated from the vehicle and exchanged between vehicles. Business models, in which the ownership of the car and of the battery is split, are also already evolving.
- The charging unit/converter. Charging units for lower energy transmission rates are residing inside the car via a power inverter using a DC power stream via the cable. Off-car charging units are used for fast-charging using DC.
- The Charging Pole. This component represents the non-mobile connector to the grid connected to a PCC (Point of Common Coupling). Currently several standards and protocols based on analogue (PWM) or digital information exchange techniques exist or are in the latest stage of development and standardization.
- Grid. The grid may be the main electricity grid ranging to the HV segment via voltage transformers and substations, but also possibly a local, disconnected microgrid.



**Figure 1 Components and processes w.r.t EV charging**

In

Figure 1 the metering, monitoring and control processes are considered. Metering is the process of generating tax compliant series of measurements of kWh values that generally are not transmitted in real-time. It means, that measurement equipment has to be calibrated and that data has to be kept for a prolonged period of time (typically years). In the chain of possible metering the leftmost metering process might take place at a high-MV/DC charging station resembling a gasoline filling station, which will be measured by standard utility telemetry. The second metering process might indicate charging at an office building with several charging poles. The third level metering, then takes place at the PCC of the building. So, the individual meter readings of charging for the cars must be available and the metered sum. A building facility manager, then, has a proposition for capacity management. Individual charging processes are billed from an energy perspective, while the aggregated power is managed from a capacity perspective, optimally using the connection capacity in time. The possibly, multi-levelled measurement approach also enables fine-grain taxation schemes for EVs to compensate gasoline taxes for vehicles. The 4<sup>th</sup> and the 5<sup>th</sup> metering layer correspond to secondary substation and HV metering. The metering data networks and metering data repositories created will be operated by one of the stakeholders. We could assume that the smart meters installed at the Points of Delivery will be operational (EC road map) when the deployment of EV occurs. Another question would be to know whether an extra meter dedicated to the charging pole will be required (specific requirements, new taxes, for EV...)

In the following discussion, the symbol  $kWh_{tc}(t, \Delta t)$  is used for the kWh-profile in which  $tc$  stands for tax-compliant and  $t$  and  $\Delta t$  indicate the measurement interval. Currently, for customers without a smart meter below a certain connection value, kWh is measured once a year over a year interval manually without any ICT (this period can vary depending on the country). Thus,  $kWh_{tc}(t, \Delta t)$ , is not available, all but for customers above the telemetry limit (customers producing or consuming more than a number of typically 5 MW). For low-consumption/production customers the time dependence of the system operation to real-time market prices is accounted for by 'Power-profiles' for clustered consumer categories. Profiles,  $kWh(t)$ , are measured for a few sample households, businesses, that belong to a certain profile. The energy consumption cost in time for these groups is accounted for by applying the normalized real-time prices over a year. The most elementary option for accounting for the impact of EV loads on the electricity system operation would be to extend the number of profiles and retain the current off-line metering scheme. For instance, if there is a 'profile' of 100000 EV charging points, it would mean, that, for approximately 20 of these, detailed measurements are done to generate an administrative profile, quantifying the cost impact in system operation for the whole customer cluster of EV charging stations.

Monitoring means generating data values of process parameters with a maximum delay/latency defined by the service application. Control means reaction of a certain control algorithm based on measured process parameters. In current electricity systems, distribution monitoring and control is performed down to the substation secondary-level using utility SCADA-systems. Commercial monitoring and control is performed via computerized, telemetry based, ICT infrastructures.

The column wise build-up of the diagrams indicates the possibility to have additional control, metering and monitoring processes at several interfaces in the loosely coupled ICT-cloud or the tightly connected physical grid infrastructure. In EV service applications, metering, control and monitoring entities possibly have identification requirements. From a software architectural point of view, adequate partitioning of these requirements, designing the right level of security and keeping the scope of data as confined as possible will help in achieving quality for these operational attributes. From an ICT perspective the design task is right-sizing of ICT-components and aggregating data at the right level to serve the business requirements.

In WP 2 a number of business concepts are described. Especially D2.2 gives a summary of business processes of stakeholders. From these processes, the following required and trusted information for entities in the configurations above to participate in intelligent grid operation regarding the EV to EVSE processes have to be made available:

- Realisations of power consumptions;  $kW_{realized}(t, \Delta t_{application})$ , transmitted with a maximal delay defined by the application  $\Delta t_{application}$ . For power distribution purposes,  $\Delta t_{application}$  will be in the order of minutes. For commercial operations, the value will range from minutes for portfolio optimization, via quarters of an hour for the imbalance market to hours for the day-ahead markets.
- Forecasts of the power consumption profile for a range of periods ahead. In an aggregated form they may be used for portfolio optimization of program responsible parties:  $kW_{forecast}(t + \Delta t_{application})$ . Similar planned parameter information is also relevant for distribution network optimization and congestion management. At a higher level, the real-time transport nominations at several levels from the grid operation perspective (TSO, DSO, congestion management) could be used in this way.
- Battery parameters including real-time and desired state-of-charge in the future:  $SOC(t)$ ,  $SOC(t + \Delta t)$ . These may be derived from travel plans.

Information to be received by the EVs from the EVSE processes pertains to the following:

- Maximal limits to the capacity (also in the future)  $kW_{max}(t)$ . These may also include transport nominations at several levels from the grid operation perspective (TSO, DSO, congestion management) translated down to the maximal power at a certain grid segment.

- Real-time and planned pricing model information:  $p(t)$ ,  $p(t+ \Delta t)$  . The schedule indicates the price at which systems operation is mapped on a certain type of EV-consumption; price plan components might include commodity components, distribution fees, availability payments and tax incentives. All three of them may change in real-time.

The stakeholder's processes, in which this information on different aggregation levels is used and identification is important can be divided into the following:

- System ancillary services (AS). Primarily voltage and frequency control are involved. For these types of services Data Delivery time requirements as well as Security Requirements are high. Quality of service requirements will be medium as will be throughput requirements.
- Portfolio optimization (PO). These include clustered VPP (Virtual Power Plant) operations like, programme following, commercial balancing and other service delivery functions. These applications are energy based. Throughput requirements and data delivery requirements will be high, because of the volumes of data transfer and the response time required from a market perspective. QoS and Security requirements are moderate, because primary grid operation functions are not involved.
- Metering, Reconciliation and Billing (MRB). Here Throughput and Data delivery requirements are Low, whereas Quality of service and Security have to be high.
- Distribution capacity optimization (DCO). Here data delivery requirements are highest, the other attributes are moderate.

The requirements for identification are strongly affected by the aggregation level of identifiable entities. Therefore, in Table 2 the minimum required aggregation level for possible service applications is contained as estimated from business model viability. The required information at the aggregation levels H (system), A (average) and L (low) in each of the world scenario's, advanced (Ad), pragmatic (Pr) and conservative (Co), is also displayed. The content of the table is discussed in the next sub-sections.

**Table 2: Data aggregation level for service applications**

	AS			PO			MRB			DC		
	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co
$kWh_{tc}(t, \Delta t)$	-	-	-	-	-	-	L	H	-	L	H	-
$kW_{realized}(t, \Delta t_{application})$	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co
	L	H	-	H	H	H	-	-	-	L	H	-
$kW_{realized}(t+\Delta t_{application})$	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co
	-	-	-	A	-	-	-	-	-	L	H	-
SOC(t), SOC(t+ $\Delta t$ )	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co
	L	H	-	A	H	-	L	A	-	L	H	-
$kW_{max}(t)$	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co
	-	-	-	A	H	-	L	A	H	L	A	-
$p(t)$ , $p(t+ \Delta t)$	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co	Ad	Pr	Co
	A	-	-	A	H	H	L	A	-	I?	H	H

The aggregation level forms the link to the design of ICT service applications and as a result to the ID requirements in the following sub-sections. The ID-requirements will be defined for the information streams for each of the three scenarios defined.

#### 4.1.1 Conservative world scenario

In the conservative scenario, the required aggregation level for data collection, metering and control is high; the power capacity constraints and prices are determined at the highest level and with low update intervals. The grid is assumed to be fed-in only from the highest voltage levels with few local distributed generation resources. As compared to more advanced Smart Grid based scenarios, there are only top-down power flows with low levels of communication. The whole measuring and control

process is central and uses only data, measured at the higher Voltage levels of the grid from the primary substation or secondary substation level. Security aspects are managed centrally, possibly via the already existing physical ICT-infrastructure. No control gateways are defined; possibly only Smart Meters at end-customer sites might be installed. This makes the ID requirements on the infrastructure not very much different from the current one. The data delivery and security requirements are high, because Identification errors here lead to errors in operating the whole electricity system. The QoS and throughput requirements are lower as, due to the high aggregation level, the system inertia is higher; disturbances will not lead to severe impacts on the whole system .

**Table 3 Evaluation of parameter and attributes**

	Throughput	Data delivery	QoS	Security
$kWh_{ic}(t, \Delta t)$	Low	High	Low	High
$KW_{realized}(t, \Delta t_{application})$	Low	High	High	High
$p(t), p(t+ \Delta t)$	Low	Low? *	Average	Low

The requirements for throughput are low in this scenario as real-time prices will be less probable. Control algorithms for intelligent vehicle charging and other types of demand response most probably will be implemented by giving price schema signals. Data delivery requirements on the other end are high as switch actions must be done in the higher voltage levels based on very reliable basis. To perform contingency and constraint management the requested data delivery delays are small. Operationally, pricing information data delivery requirements are low, as in the scenario no real-time pricing or valuation of energy is defined. Varying prices will be broadcasted by setting varying tariff scheme parameters.

#### 4.1.2 Pragmatic world scenario

In the pragmatic world, a number of processes will be actively controlled at a high system level; capacity management extends to the medium voltage system level. In Table 4 the requirement attributes are again displayed for the EV <> EVSE identification process.

**Table 4 Evaluation of parameter and attributes**

	Throughput	Data delivery	QoS	Security
$kWh_{ic}(t, \Delta t)$	Low	High	High	High
$kW_{realized}(t, \Delta t_{application})$	Low	High	Low	High
$kW_{forecast}(t+\Delta t_{application})$	Low	Average	Average	High
$SOC(t), SOC(t+ \Delta t)$	Low	Average	Average	High
$kW_{max}(t)$	Average	Average	High	Average
$p(t), p(t+ \Delta t)$	Average	Average	Low	Low

The ID requirements are highest in this case for data delivery and security, as high level functions are involved; e.g. in order to secure portfolio management of EVs in a certain grid control area data transfer has to be guaranteed and settlement of kWh has to be managed secure Direct charge control of small customers will hardly be possible on an individual or low aggregation basis as the requirements have to be met by a large number of individual nodes in the ICT-network. Sending (local) price model signals, on which vehicle chargers intelligently adapt their strategy, will relieve the ID requirements considerably.

### 4.1.3 Advanced world scenario

In the advanced world, a number of critical processes are actively controlled at a medium and high system level and some even at low system levels. The contribution of each participant to the operation of the power system as a whole is mapped as closely as possible to value creation and asset management. Billing processes are done in real-time using micro-transactions as used in other sectors (e.g. telecom).

**Table 5 Evaluation of parameter and attributes**

	Throughput	Data delivery	QoS	Security
$kWh_{ic}(t, \Delta t)$	Average	High	High	High
$kW(t, \Delta t_{application})$	High	High	Low	High
$kW(t + \Delta t_{application})$	High	Average	Average	High
$SOC(t), SOC(t + \Delta t)$	Average	Average	Average	High
$kW_{max}(t)$	Average	Average	High	Average
$p(t), p(t + \Delta t)$	Average	Average	Low	Low

The number of nodes involved and the required aggregation of measurement and control data would lead to nearly not satisfiable tense ID-requirements for intelligent charging infrastructures. Only exchanging (localized) pricing information to coordinate the EV charging processes to satisfy grid optimization applications discussed, might lead to manageable ICT-systems.

### 4.1.4 Recommendations

For all applications in all scenarios, there might be blocking ID requirements. In a large number of complex information system implementations, related to in complexity to the EV<>EVSE interaction, problems have occurred. Especially in the Netherlands and the Scandinavian countries, the introduction of communicating meters has led to strong privacy concerns which have delayed and in some cases hindered the introduction. In order to prevent this, it is necessary to optimize the scope, the aggregation level and the location of metering, control and monitoring data to the right locations. Distributed coordination mechanisms provide fine-grained scoping of data interchanged and access mechanisms that do not uncover ID-information unnecessarily. In these mechanisms, pricing related signals form a natural way of aggregation, which does not stress throughput, data delivery, QoS and security requirements to the limits as complex hardly maintainable central control mechanisms. By not identifying the car, that is currently charging, some of the concerns could also be taken away.

## 4.2 Power exchange process

The interactions between the actors that are described in the communication flow chapter in the power exchange process from deliverable 4.1 are not messages in a scent that technical requirements can be derived from them, since no actual data is defined at this stage. Each interaction may consist of several messages for individual data points, although they will however be considered as aggregated messages in order to define a minimum set of parameters that need to be transmitted between the actors. In the following chapters the interactions in the three different models will be described.

### 4.2.1 Conservative world scenario

The conservative world scenario has no changes to present day regarding DSM. It is considered for that world that there are only Time of Use tariffs with time periods for long term (annually at least) which are stored in the meters. Therefore no ICT requirements are envisaged.

## 4.2.2 Pragmatic world scenario

Table 6 shows the interactions between the actors and the minimum set of parameters exchanged in the pragmatic world model as described in the sequence diagrams from the section communication flow of the power exchange process.

**Table 6: Minimum set of parameters**

#	From	To	Content	Parameters
1	R/A <sup>3</sup>	DSO	Request for TOU tariffs	retailer id, request id, volume
2	DSO	DSO	Feasibility check	none
3	DSO	R/A	Confirmation of TOU tariffs	request id, start time, stop time, volume
4	R/A	Market	Offers for energy procurement	retailer id, offer id, start time, stop time, volume, buy price
5	PP/ET <sup>4</sup>	Market	Offers for energy provision	et id, offer id, start time, stop time, volume, sell price
6	Market	Market	Matching process	none
7	Market	PP/ET	Result of matching	offer id, start time, stop time, volume, sell price
8	Market	R/A	Result of matching	offer id, start time, stop time, volume, buy price
9	R/A	Customer	Offer for TOU tariff contract	offer id, start time, stop time, volume, price
10	Customer	R/A	Conclusion of contract	offer id, accept/decline
11	R/A	DSO	Prices and time period of TOU	retailer id, start time, stop time, volume, delivery point
12	DSO	DSO	Validation of TOU-tariffs	none
13	DSO	TSO	Demand activities within distribution network	DSO id, start time, stop time, volume, delivery point
14	Market	TSO	Market result	start time, stop time, volume, delivery point
15	TSO	TSO	Validation of results	none
16	TSO	Market	Confirmation of market results	start time, stop time, volume, delivery point, accept /decline
17	TSO	DSO	Confirmation of demand activities	start time, stop time, volume, delivery point, accept /decline
18	DSO	Customer	Start signal for TOU period	start time, stop time

Table 7 describes a quantification of the interactions described in the power exchange process based on the parameters defined in Table 6. The size of each parameter that should to be transmitted can be assumed to 5kb. 5kb give each parameter the option to allocate up to 20 fields in database where each field consists of 256 byte. This will allow metadata for each parameter to be stored. The actual size of each interaction will however depend on how much overhead data that is needed and how many actual messages that is sent (which is highly dependent on protocol, security, etc.). The interactions should not be performed more than once if all data is transmitted correctly to the receiver. However the interaction between the actors will depend on how many actors there are with the same function. Some interactions will require multiple interactions with other actors in the same sequence while others only require one. For instance: Actor “Market” will send information to several retailers in the same sequence, while the interaction between the customer and retailer will only require one interaction, because there exists several retailers connected to the market but the customer is only connected to one retailer. The interactions from the market will therefore require higher throughput than the interaction from the customers. To calculate the throughput we introduce “receivers”. The throughput can be calculated as following: (number of parameters) x (receivers) = Throughput. The number of receivers will range from one to the total number of actors with the same function. In table 7 the number N will

<sup>3</sup> R/A: Retailer/Aggregator

<sup>4</sup> PP/ET: Power producer/Energy Trader

be considered as a large number for each line where there are several receivers to get the “worst case” calculation therefore the throughput requirement will be high on each line where there exists several actors with the same function. If the number of actors is low the requirement on the throughput would be average. The interactions 1-17 can accept a low latency and average QoS since these interaction are not time critical, there is time to re-send information if the receiver cannot interpret it. The interaction 18 is more time critical and will therefore have higher demands on latency and QoS. All interactions can be considered as confidential and therefore high security is needed.

**Table 7: Quantification of parameters**

#	Total number of parameter	Receivers	Throughput	Latency	Reliability	Availability	Security aspects
1	4	N	High	Low	Average	Average	High
2	None	None	N/A	N/A	N/A	N/A	N/A
3	4	N	High	Low	Average	Average	High
4	6	1	Average	Low	Average	Average	High
5	6	1	Average	Low	Average	Average	High
6	None	None	N/A	N/A	N/A	N/A	N/A
7	5	N	High	Low	Average	Average	High
8	5	N	High	Low	Average	Average	High
9	5	1	Average	Low	Average	Average	High
10	2	1	Average	Low	Average	Average	High
11	5	N	High	Low	Average	Average	High
12	None	None	N/A	N/A	N/A	N/A	N/A
13	5	N	High	Low	Average	Average	High
14	4	N	High	Low	Average	Average	High
15	None	None	N/A	N/A	N/A	N/A	N/A
16	5	N	High	Low	Average	Average	High
17	5	N	High	Low	Average	Average	High
18	2	N	High	Average	High	High	High

### 4.2.3 Advanced world scenario

Table 8 shows the interactions as described in the sequence diagram from section communication flow of the power exchange process advanced world model.

**Table 8: Minimum set of parameters**

#	From	To	Content	Parameters
1	Retailer	Market	Offers for energy procurement	retailer id, offer id, start time, end time, volume, buy price
2	PP/ET	Market	Offers for energy provision	producer id, offer id, start time, end time, volume, sell price
3	Market	Market	Matching process	none
4	Market	PP/ET	Results of matching	offer id, start time, end time, volume, sell price
5	Market	Retailer	Results of matching	offer id, start time, end time, volume, buy price
6	Retailer	Customer	Offer for ToU tariff contract	offer id, start time, end time, volume, buy price
7	Customer	Retailer	Conclusion of the contract	offer id, accept/decline
8	Aggregator	Customer	Offer for flexibility services	offer id, start time, end time, volume, buy price, sell price
9	Customer	Aggregator	Conclusion of the contract	offer id, accept/decline

10	TSO	Market	Demand for ancillary services	offer id, start time, end time, volume, delivery point
11	Aggregator	Market	Offers for ancillary services	Aggregator id, offer id, start time, end time, volume, buy price, sell price, delivery point
13	Market	Market	Matching process	none
15	Market	Aggregator	Results of matching	offer id, start time, end time, volume, buy price, sell price
16	Market	TSO	Results of matching	Aggregator id, offer id, start time, end time, volume, buy price, sell price, delivery point
17	Aggregator	DSO	Demand activities due to the provisioning of ancillary services	Aggregator id, start time, end time, volume, delivery point
18	Retailer	DSO	Load schedule for EVs	retailer id, start time, end time, volume, delivery point
19	DSO	DSO	Validation/modification	none
20	DSO	TSO	Demand activities within distribution network	DSO id, start time, end time, volume, delivery point
21	Market	TSO	Market results	start time, end time, volume, delivery point
22	TSO	TSO	Validation of results	none
23	TSO	Market	Confirmation of market results	start time, end time, volume, delivery point, accept/decline
24	TSO	DSO	Confirmation of demand activities	start time, end time, volume, delivery point, accept/decline
25	DSO	Aggregator	Confirmation/modification of demand activities	start time, end time, volume, delivery point
26	DSO	Retailer	Confirmation/modification of load schedule for EVs	start time, end time, volume, delivery point
27	Retailer	Aggregator	Price signal	start time, end time, volume, sell price, buy price
28	DSO	Aggregator	Call of ancillary service	start time, end time, volume, delivery point
29	Aggregator	Customer	Control signal for ancillary services/price for energy supply	start time, end time, volume

Table 9 describes a quantification of the interactions described in the power exchange process based on the parameters defined in Table 8. The size of each parameter that should be transmitted can be assumed to 5kb as in the pragmatic world. The calculation of throughput will be performed in the same way as in the pragmatic world. The interactions 1-26 can accept a low latency and average QoS since these interaction are not time critical, there is time to re-send information if the receiver cannot interpret it. The interactions 27-29 are more time critical and will therefore have higher demands on latency and QoS. All interactions can be considered as confidential and therefore high security is needed.

**Table 9: Quantification of parameters**

#	Total number of parameter	Receivers	Throughput	Latency	Reliability	Availability	Security aspects
1	6	1	Average	Low	Average	Average	High
2	6	1	Average	Low	Average	Average	High
3	None	none	N/A	N/A	N/A	N/A	N/A
4	5	N	High	Low	Average	Average	High
5	5	N	High	Low	Average	Average	High
6	5	N	High	Low	Average	Average	High
7	2	1	Average	Low	Average	Average	High
8	6	N	High	Low	Average	Average	High
9	2	N	High	Low	Average	Average	High
10	5	1	Average	Low	Average	Average	High

11	8	1	Average	Low	Average	Average	High
13	None	none	N/A	N/A	N/A	N/A	N/A
15	6	N	High	Low	Average	Average	High
16	8	N	High	Low	Average	Average	High
17	5	N	High	Low	Average	Average	High
18	5	N	High	Low	Average	Average	High
19	None	none	N/A	N/A	N/A	N/A	N/A
20	5	N	High	Low	Average	Average	High
21	4	N	High	Low	Average	Average	High
22	None	none	N/A	N/A	N/A	N/A	N/A
23	5	N	High	Low	Average	Average	High
24	5	N	High	Low	Average	Average	High
25	4	N	High	Low	Average	Average	High
26	4	N	High	Low	Average	Average	High
27	5	N	High	Average	High	High	High
28	4	N	High	Average	High	High	High
29	3	N	High	Average	High	High	High

### 4.3 Billing process

This section describes and evaluates in detail the ICT requirements needed for billing process involving electric vehicles according to the features and reference ranges specified above. The requirements are defined for each of the three scenario worlds discussed in previous WPs. Additionally, the different elements of the billing process are described in detail in the deliverable D4.2 with a sequence diagrams of the data exchange between the stakeholders and the different roles respectively.

In the billing process, there are data exchanges between all stakeholders involved in this process. Thus, the evaluation of ICT requirements will depend to the relationship between them in each of the three scenario worlds.

#### 4.3.1 Conservative world scenario

The conservative scenario world pursues a business as usual approach. Therefore, no great additional ICT infrastructure would be needed in this scenario and the integration of innovations into the system is limited.

As commented above, deliverable D4.2 explains the roles and stakeholders of communications in the billing process and describes all possible data exchange that can be considered in the EV charging. With this knowledge, it is possible to evaluate the ICT requirements of this specific billing process.

Moreover, the conservative scenario must include the communication flow needed to perform the authorization billing process and bill the customer for the energy taken for charging the EV. In order to perform the processes described in these information flows, the involved stakeholders need to satisfy some ICT requirements. Thus, it is possible to define the requirements Throughput, Data Delivery, Quality of Service (reliability and availability) and Security Aspects for this scenario world.

Table 10 summarizes all the billing process requirements in this scenario for all the communication relationships involved.

**Table 10: Billing process requirements in the ‘conservative scenario’**

Process	Customer – ICT Gateway Operator	MPO/MSP and/or ICT Gateway Operator – CH	CH - Retailer	Retailer - Customer	CH - DSO	DSO - Retailer
<b>Throughput</b>	low	high	high	low	high	high
<b>Latency</b>	low	low	low	low	low	low
<b>Reliability</b>	high	high	high	high	high	high
<b>Availability</b>	average	average	low	low	low	low
<b>Security aspects</b>	high	high	high	high	average	average

- **Throughput:**

The minimum data rate required for billing processes involving electric vehicles must be large enough to handle the data volume treated. In other words, the throughput will depend on the size and frequency of messages and data exchanged between all stakeholders involved in this process. However these needs may differ according to the communication process used and the stakeholders involved. Thus, it is necessary to know all the communications processes that occur in the conservative scenario in order to define the throughput requirements according to the reference ranges defined above.

When an individual Customer accesses the Charging Pole using the ICT Gateway Operator in order to request an authorization, the level of throughput can be lower than the other processes because the amount of data is smaller. The same occurs when the Retailer, using the metering data, sends the invoice to the Customer. The required bandwidth per line at the EV pole to the EV is supposed to be approximately 213,3 bps. However, in the conservative scenario other business models exist and simpler processes can also be deployed.

On the other hand, the throughput would be higher within the other stakeholders because the amount and frequency of data is more important. This increase is caused by the necessity of communicating the aggregated information of various EV charging simultaneously. At that level, the required bandwidth is supposed to be approximately 8,5 Mbps. The ICT Gateway Operator sends detailed metering data to the Clearing House for each charge operation; the Clearing House sends the metering data to the Retailer for its customers and provides all the metering data to the DSO for all the charging points in its grid. The same occurs with the DSO, which can bill the Energy Retailer for the grid usage. For these reasons, a high throughput is defined in the cited processes. As said before, these requirements are described for the more demanding situation, as other simpler business models can be applied in the conservative scenario.

- **Data delivery time (Latency):**

The billing of an EV charge process includes, among others, the exchange of metering data from the Clearing House, the respective identification numbers from the DSO, Retailer, ICT Gateway Operator or Customer, accounting data for grid usage and the correspondent invoices. All these information transmitted during the billing process is not time-critical, as they do not put the health of the grid at risk.

Besides, the data required can be stored some time and can be retrieved again. Thus, the requirement of data delivery time is low, according to the reference ranges defined above. This is because the information is usually not of an urgent nature.

- **Quality of Service (Reliability and availability):**

The quality of service is an important issue in the billing process because it deals with economic issues and confidential information. In this aspect, a high or average level of reliability is needed in order to avoid errors and data corruption during the exchanges of information between the agents involved.

Customer, ICT Gateway Operator, Clearing House and Retailer communicate to perform the authorization process, which includes all the actions needed to authenticate the contract that shall be used for energy billing and to authorize the charge process. The high level of reliability is necessary in the authorization process between these previous agents. At the same time, in metering and invoice related processes no errors can be allowed and the reliability requirements are also high. However, as have been commented in the previous section, it is necessary to consider a compromise between transmission speed and this high level of reliability.

On the other hand, the availability required is low and non-critical because during the billing process in conservative scenario, the data can wait until link becomes available. Thus, the devices will generally have sufficient data storage capacity, so that data can be stored when the communication link is not available, and send when the link becomes available again. It is known that this information is confidential and very important, but the data don't have to be transmitted in a specified instant. But as have been commented before, some agents may not have enough storage capacity, like the ICT Gateway Operator. In this case, the availability level can be average.

- **Security Aspects:**

During the billing process, confidential and personal information can be needed to be exchanged between the actors involved in that process. For that reason, high or average levels of security need to be achieved in order to protect the system from a wider variety of threats and vulnerabilities such as theft of financial and personal data, network failures, unauthorized access, viruses, cyber-attacks, etc.

An example of critical information that is exchanged in that process is when the Customer subscribes a contract with the Energy Retailer. It then provides to the Clearing House all the relevant contractual information, including the specific energy tariff for that particular Customer. The same high level of security is necessary when the Customer accesses to the charging infrastructure requesting for an authorization because this request contains confidential information. After a correct authorization, the charge operation can begin.

After the authorization process, the communications needed to bill the Customer for charging the EV also requires a high level of security. In this case, the information sent regarding detailed metering data can need an average level of security. These cases are communications between DSO, Clearing House and Retailer.

### **4.3.2 Pragmatic world scenario**

In the pragmatic world scenario it is expected that the DSO will assume some functions in the EV's recharge process. These actions will be the ones regarding those who concern to distribution grid availability. In order to achieve some degree of charge control, some additional ICT infrastructure will be needed.

This scenario world is more complex than the conservative scenario. In this case, the technical functions and communications flows in the billing process are performed by more actors. All the data exchange needed to assure the correct communications with the stakeholders will be studied in order to define the ICT requirements. The pragmatic world offers flexibility services and manages the congestion of the network, so the actors are involved in more processes with more exchanged data. Then, the ICT requirements can be more restrictive than the conservative scenario.

The requirements studied are the same in all scenarios, but the stakeholders involved can vary.

Table 11 summarizes all the billing process requirements in this scenario world.

**Table 11: Billing process requirements in the ‘pragmatic scenario’**

Process	Customer - MPO/MSP and/or ICT Gateway Operator	MPO/MSP and/or ICT Gateway Operator – CH	CH - Retailer	Retailer - Customer	CH - DSO	DSO - Retailer
<b>Throughput</b>	low	high	high	low	high	high
<b>Latency</b>	low	low	low	low	low	low
<b>Reliability</b>	high	high	high	high	high	high
<b>Availability</b>	low	low	low	low	low	low
<b>Security aspects</b>	high	high	high	high	average	average

Process	CH - TSO	CH - BRP	TSO - BRP	BRP - Retailer	DSO - TSO	CH - TSO
<b>Throughput</b>	high	high	high	high	high	high
<b>Latency</b>	low	low	low	low	low	low
<b>Reliability</b>	high	high	high	high	high	high
<b>Availability</b>	low	low	low	low	low	low
<b>Security aspects</b>	average	average	average	average	average	average

- **Throughput:**

Some of the communications processes are explained in previous scenario world, but others have different needs and more stakeholders involved.

The Customer accesses the charging infrastructure requesting an authorization and the ICT Gateway Operator presents the tariffs to the Customer. Then, the retailer sells energy to the Customer (could contain different prices for respective energy purchase, maximum of occupied power...) and grid usage (possibly flexible). The required bandwidth per line at the EV pole to the EV is supposed to be approximately 928 bps. Hence, the amount of messages involving the Customers is more important than the previous scenario, but not enough to increase the required level of bandwidth in these cases.

The other actors involved send messages that contain metering data, contractual parameters, bills for the grid fees, load profiles, some grid time series and so on. At that level, the required bandwidth is supposed to be approximately between 37,1 Mbps. Thus, with these communication flows, including between the new actors in this scenario world, a high bandwidth will be adequate, too.

- **Data delivery time (Latency):**

In the pragmatic scenario, all the communication flows during the billing process are not time-critical according to the requirement of data delivery time defined above. This includes, in addition to communication processes included in previous scenario, all the communication flows between TSO and BRP. They send balance group sum time series, invoices for balancing energy and charge balance energy.

Moreover, the stakeholders are smart and have an information storage capacity in order to retrieve the messages after. For example, the Retailer’s contract envisages different tariffs depending on the time in which energy is taken (TOU tariffs). Then, the charge could be delayed in order to use a more convenient energy tariff (for example at night). Hence, the requirement of data delivery time is low, according to the reference ranges defined in previous section.

- **Quality of Service (Reliability and availability):**

Also in the pragmatic scenario, a high level of reliability is necessary in the billing process because treats confidential and personal information. Mainly, the stakeholders involved with the authorization



process messages that include contractual information, contract ID or tariffs, for instance. For that reason, the communication flows between all stakeholders require a high level of reliability.

In this scenario are present some services in order to offer load-shaping and manages the network congestion, but in the billing process, the data can wait until link becomes available. In addition, in pragmatic scenario the agents may have enough storage capacity for the amount of data treated including the ICT Gateway Operator, which controls the isolating switch of the Energy Charging Gateway and communicates with the Vehicle. In conclusion, a low level of availability will be required.

- **Security Aspects:**

Generally, the billing process manages confidential information, so it is necessary a high level of security between the agents which send this kind of data. Hence, Customer, MPO/MSP and/or ICT Gateway Operator, Clearing House Operator and Retailer require a robust security in order to avoid some kind of threat or vulnerability. An example of this is when the ICT Gateway Operator forwards the request to the Clearing House, which already has all the contractual information for that Customer.

However, the information sent by the other agents can require a lower level of security. For example, periodically TSO sends to BRP sum time series of balance group matched with grid time series for respective Balance Responsible Party; and charges balance energy which is purchased by TSO. These communications may work with an average level of security.

### 4.3.3 Advanced world scenario

The advanced scenario world allows the Aggregator actor, and in this scenario it is expected to make possible the control of the load considering network congestion and other economic factors. A high degree of ICT technologies is expected in order to achieve all these new functions and actions. Furthermore, this scenario also contemplates V2G (Vehicle-to-Grid) technology. This can modify some aspects of the billing process that are commented below.

Other new actors are presented in this scenario, which perform important communication flows, in order to coordinate the V2G services and active demand requests. All this has been explained in deliverable D4.2. For example, the Market Coordinator accepts active demand requests from different purchases and request Aggregators to send offers. Then, the Market Operator establishes the price of AD services and decides which offers and which requests are to be accepted.

Table 12 summarizes the ICT requirements for these and others communication flows for billing process in the cited advanced scenario.

**Table 12: Billing process requirements in the ‘advanced scenario’**

Process	Customer - MPO/MSP and/or ICT Gateway Operator	MPO/MSP + Charging pole - CH	CH - Retailer	Retailer - Customer	CH - DSO	DSO - Retailer
<b>Throughput</b>	low	high	high	high	high	high
<b>Latency</b>	low	low	low	low	low	low
<b>Reliability</b>	high	high	high	high	high	high
<b>Availability</b>	low	low	low	low	low	low
<b>Security aspects</b>	high	high	high	high	average	average

Process	DSO - Control Service Provider	Control Service Provider – CH	CH - Aggregator	BRP – Market Coordinator	Market Coordinator - Aggregator	DSO - Control Service Provider
<b>Throughput</b>	high	high	high	high	high	high
<b>Latency</b>	low	low	average	average	average	low
<b>Reliability</b>	high	high	high	high	high	high
<b>Availability</b>	low	low	average	average	average	low
<b>Security aspects</b>	average	average	high	high	high	average

- **Throughput:**

As mentioned above, the amount and frequency of messages and data exchanged in the billing process for this scenario will be higher than in the previous scenarios.

For example, the Market Coordinator combines all the active demand requests and sends to all the Aggregators the result of this combination. Then, each Aggregator, on the base of the status of its Customers, makes an offer to the Market Coordinator. They decide which offers and requests are accepted and then prices and finally the Aggregator sends active demand offers to all its Customers. These communication flows show that Aggregator and Market Coordinator manage a big amount of data, so they require a high level of throughput.

All the rest of processes can work with a high level of throughput, except the processes involving communications between the Charging Pole and the Customer that, as in other scenarios, have a low level of requirement. The reason is that, unlike in other cases, they do not need to aggregate the information of several EVs that can be charging simultaneously.

- **Data delivery time (Latency):**

As in the other scenarios, the communication flows during the billing process are not time-critical. Nevertheless, the advanced scenario works with real-time balancing services, which modifies the behaviour of Customers. It is possible that, due to load reduction or delay, other stakeholders could receive economic losses (for example the Retailer). The compensation of such economic losses depends on the regulation policies and on the commercial agreements among the stakeholders. In any case, the billing process is not strictly related to these communication flows, so it is not necessary a higher level of data delivery time. In conclusion, both Aggregator and Market Coordinator, as managers of the services and processes, may require an average level of latency. Then, in these agents, the period it takes from the instant a command or request is initiated from one device to another device until the instant the receiving device respond to the command or request, will be faster than the other stakeholders.

- **Quality of Service (Reliability and availability):**

In order to avoid some kind of errors in the billing process, a high level of reliability will be necessary between the stakeholders which manage confidential information. Overall, a high level of reliability is necessary in the authorization processes data and between the Clearing House and the other stakeholders involved with metering data.

Related with availability, the data treated in the billing process can wait and can be stored until link becomes available. A low level of availability will be defined in all the communications flows except between the transmissions that involve the aggregator and the Market Coordinator. These both agents are the managers of the system and it will be optimal to define an average level of availability.

- **Security Aspects:**

The actors involved with the authorization and contractual information, including tariffs and invoices, require a high level of security. These communication flows are when the Customer subscribes a contract with the Retailer or when the Retailer provides to the Clearing House all the contractual information or when the Customer accesses the charging infrastructure requesting an authorization or when the ICT Gateway Operator forwards the request to the Clearing House. Also the Aggregator and the Market Coordinator may require a high level of security because they manage confidential information of the Customers. An average level of security will be enough in the other processes.

#### ***4.4 Summary of ICT requirements***

Once the main features for evaluation criteria have been described and the ICT requirements have been evaluated in detail, this chapter summarizes these ICT requirements for each area regarding EV charge. In the previous sections, the ICT requirements were defined for each process: identification, power exchange process and billing process. The most adequate method of study has been used for each one. Then, this section tries to summarize all these results in order to choose, in the following chapter, the recommended technology for each case. After analysing these processes, it is clear that they have aspects in common and, as a result, three areas or communication paths have been detected: ID communications, Electric Vehicle to Charging Pole communications and Charging Pole upstream communications. However, this last one communication path includes the power exchange process and the billing process communications. Hence, once studied the ICT requirements deeply according to the communication process, now it is needed to separate them in these levels of communications in order to define the adequate technology for each of them.

User or Electric Vehicle ID communications include the identification when the customer accesses the charging infrastructure requesting for an authorization, for instance. In addition, the vehicle owners and/or the vehicle users have a contract ID with the retailer, which shall be used for energy billing. All these communication flows are included in this area and they must ensure a set of security requirements to assure the privacy of the EV user's personal information.

Electric Vehicle to Charging Pole communications summarize the aspects regarding the communication of the EV's intelligence with the charging infrastructure in order to identify the vehicle and recharge the battery under the conditions set by the manufacturer of the battery, for instance. As have been discussed, in advanced world scenarios the EV can be understood as a mobile electricity storage component in the Smart Grid, so the ICT requirements must be adequate to fulfil these new needs.

Charging Pole upstream communications include all the communication data flows regarding sending information outwards the Charging Pole. It includes the ID for electric vehicle supply equipment, power exchange and billing processes. As have been studied in this and in previous deliverables, the development of ICT solutions with respect to massive introduction of EVs requires exchanging information between many stakeholders. These stakeholders are different according to the scenario world applied, so the requirements are also different, as have been studied in previous sections. Retailer, DSO, TSO, Clearing House, Aggregator, BRP, Market Coordinator and so on, are the agents involved in this level of communication.

Then, Table 13, Table 14 and Table 15 summarize the ICT requirements of each communication path in the conservative, pragmatic and advanced scenarios, respectively. The upstream communications of the Charging Pole is separated in the power exchange and the billing process communications. As it has been commented above, in the power exchange process, the conservative world scenario has no changes to present day, so no ICT requirements are envisaged. On the other hand, the billing process has similar ICT requirements in the three scenario worlds, and only has higher requirements in Advances scenario due to V2G. The ranges used are according with the studies and assessments described above.

**Table 13: Summary of ICT requirements in the ‘conservative scenario’**

	Features				
	Throughput	Latency	Reliability	Availability	Security aspects
<b>Customer ID communications</b>	low	average	high	low	high
<b>Electric Vehicle to Charging Pole communications</b>	low	average	high	low	high
<b>Power exchange process communications</b>	-	-	-	-	-
<b>Billing process communications</b>	high	low	high	low	high

**Table 14: Summary of ICT requirements in the ‘pragmatic scenario’**

	Features				
	Throughput	Latency	Reliability	Availability	Security aspects
<b>Customer ID communications</b>	low	average	high	average	high
<b>Electric Vehicle to Charging Pole communications</b>	low	average	high	average	high
<b>Power exchange process communications</b>	average	average	high	average	high
<b>Billing process communications</b>	high	low	high	low	high

**Table 15: Summary of ICT requirements in the ‘advanced scenario’**

	Features				
	Throughput	Latency	Reliability	Availability	Security aspects
<b>Customer ID communications</b>	average	average	high	high	high
<b>Electric Vehicle to Charging Pole communications</b>	average	average	high	high	high
<b>Power exchange process communications</b>	high	average	high	high	high
<b>Billing process communications</b>	high	average	high	average	high

## 5 Recommendations

After doing a review of technologies and evaluating the ICT requirements, this chapter studies in detail the best technology for each communication process. As it has been described in the previous section, the communication processes involved with the infrastructure of electric vehicles are divided in four communication levels. Consequently, each of them has different ICT requirements and needs, so the recommended technologies must be properly chosen for each of them. Nevertheless, the power exchange and the billing processes have similar ICT requirements and architecture, so these upstream communications of the Charging Pole should use the same technologies. Therefore, the objective of this section is to select specific technology solutions for the architecture of each of the interfaces described above. Each interface has been analysed and a certain communication method will be assigned in order to provide full communication needs for each interface.

Table 16 summarizes the recommended technologies for each communication level in the different scenario worlds. The discussion of the recommended technologies is explained below.

**Table 16: Recommended technologies**

	Scenario worlds		
	Conservative	Pragmatic	Advanced
<b>Customer ID communications</b>	RFID	RFID	RFID NFC
<b>Electric Vehicle to Charging Pole communications</b>	CAN-bus, PWM	CAN-bus PLC	CAN-bus PLC
<b>Power exchange process communications</b>	-	GPRS, UMTS, PLC, Ethernet,	GPRS, UMTS, PLC, Ethernet, WiMax
<b>Billing process communications</b>	GPRS, UMTS, Ethernet	GPRS, UMTS, PLC, Ethernet,	GPRS, UMTS, PLC, Ethernet, WiMax

### 5.1 Customer ID communications

In private charging, the identification process could not be necessary as the charging point is always used by the same customer. Apart from private charging, there are other situations and business models in which the user identification process would also not be necessary. Examples of these could be the payment with credit or prepaid card for public parking places, or when the owner of a public charging pole has a contract with his own retailer, where the customer identification is not required. These situations are independent of the scenario world considered.

For the other cases where identification and authorization are required, security and reliability are the most important factors, and as a result, their requirements for these factors are high. However, the throughput is not critical. RFID, which is highly suitable for use for authentication, is an implanted technology with simplicity for the user and it only requires the installation of a RFID system reader integrated into the Charging Pole. This is an adequate solution in all scenarios because of its security, reliability and cost-effectiveness. Using a Smart Card is advantageous when more complex features are required. It is a secure technology and includes an embedded integrated circuit chip with internal memory, which can be used to perform more added services in addition to mere identification such as financial transactions. These additional features make them more expensive than RFID. It could be difficult their implantation, in particular when these additional services are not required. Moreover, in advanced world, when the users would have compatible phones, also a NFC technology may be used because it is a highly secure and reliable technology. The requirements regarding throughput, latency and availability will be easily covered with these cited technologies.

It also may be possible to use Bluetooth or Wi-Fi technologies with user’s mobile phone, but they require additional devices and some level of configuration by the user. These wireless technologies, as

well as Zigbee, have an adequate degree of security, although, as they are wireless, the threat of interception of sensitive user's data exists. The contract ID and the billing data need a high level of security. On the other hand, technologies such as PLC or UMTS require the installation of more complex systems and they are more appropriate for long range data transmission, than in the identification of the user's vehicle.

## ***5.2 Electric Vehicle to Charging Pole communications***

CAN-bus and PLC are the most adequate technologies in this need of communications. CAN-bus was initially developed for applications in automobiles and therefore the platform of the protocol is a result of the requirements in the automotive area. This technology offers a solution to manage transmissions between multiple central processing units like the communication between the vehicles, through the Battery Management System (BMS), and the Charging Pole. Hence, CAN-bus is adequate and follows the ICT requirements described in previous sections, including the advanced scenario with the use of V2G. The throughput needed will be slightly higher when V2G has been implemented in order to control the charging or discharging process, but even then it is expected that CAN-bus will fulfil the requirements. Also PWM is a favourable method of communication using the standard SAE J1772. Thus, PWM signal allows the charge spot to enable simple load control. PLC is also well suited in pragmatic and advanced scenarios but is more complex and needs a higher investment. This investment, if it is necessary, can be justified because PLC has higher throughput and range than CAN-bus and PWM technologies.

On the other hand, wireless technologies such as Wi-Fi, Bluetooth, Zigbee, GPRS and UMTS require the installation of more equipment. Besides they have higher cost and lower level of reliability and security. Hence, they are not adequate in this use case.

In any case, the manufacturers of EVs and Charging Poles have the final decision about which protocol or communication method would be used between the EV and the Charging Pole. In addition, current standardization processes under development will help to determine which communication method will be used in the future.

## ***5.3 Upstream communications of the Charging Pole:***

In this section, a study to define the technical recommendations for the upstream communications of the Charging Pole is presented. This communication path should be understood as a general system architecture where the different stakeholders involved can obtain or share the information required (the Charging Pole itself, DSO, TSO, Aggregator, Market Coordinator, etc.). The power exchange process and the billing process are included in this architecture. As has been studied in previous section, they have similar ICT requirements. Then, it should be recommended the use of the same kind of infrastructure and communication method in both processes. Basically, the power exchange process involves communications with stakeholders such as the DSO, while billing process is related with actors such as Aggregator or the Retailer. When agreements can be achieved between the owners of the two communication interfaces, the sharing of the same communication path is highly recommended. Then, the communication interfaces can remain separately by the use of virtual private networks over the same communication path.

As defined previously, the interfaces between all stakeholders involved have different ICT requirements, so, several technologies of communication may be combined. Obviously, the architecture is flexible and allows integrating various technologies, achieving interoperability and coexistence of different solutions that can consist of various communication protocols and physical modulations.

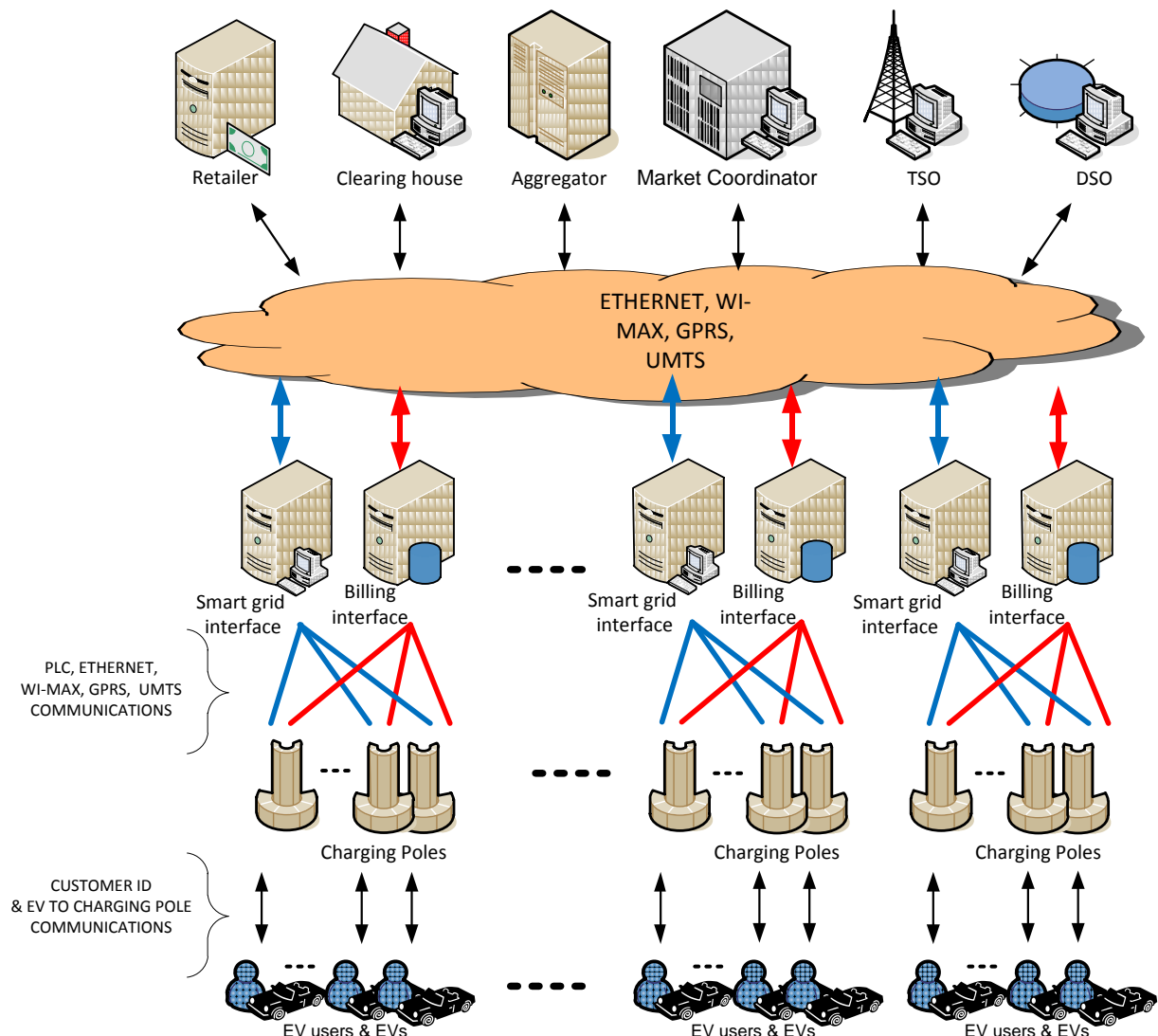
This section has adopted this approach in order to be able to incorporate and provide a complete communication system structure in the future scenarios. Thus, the definition of the ICT requirements takes into account the needs of the different agents involved and allows offering the correct choice for

all scenarios. However, when analysing widespread communication architectures, not only satisfying the communications requirements is important, the costs and an easy implementation are also critical factors.

Nowadays, there are several ways to implement the communication between the Charging Poles and the main system, which are strongly related with the location or environment of the pole. In rural areas, where Charging Poles are more dispersed, the communication is recommended to be performed via existing PSTN copper networks or GSM network from a single pole to the information system. In contrast, in urban areas, where many Charging Poles are concentrated in small areas, the data from multiple poles are sent to concentrator process running on a computer. A control gateway, as used for Automated Meter Management (AMM) might be used for this. Then, the concentrator sends the data to the information system.

Figure 2 illustrates the basic architecture of the main agents involved in the charging process of the EV. The proposed architecture takes into account the smart grid interface and the billing interface, which are related with the power exchange process and billing process, respectively. These actors manage the information obtained from the concentrators (if present) or directly from the Charging Poles. Then, they communicate with the upstream stakeholders such as DSO, TSO, Aggregator and so on. As described before, the Charging Pole is remotely managed by the Aggregator and DSO, either directly through the wide-area communication interface, or indirectly via a concentrator.

Figure 2 only considers the first case, but the concentrator can be easily understood as a group of Charging Poles.



### Figure 2: ICT architecture

Following this architecture, the Charging Pole upstream communications can be divided into two main parts; the last mile and the rest of the upstream network. The last mile communications are covering the last path of short distance of the route from the concentrators towards the customers' house/office/public location. The number of Charging Poles that can be grouped in each Concentrator is highly dependent on the used technology for the last mile and the density of Charging Poles present in the area. This number is typically between 200 [12] and 800 [13]. One of the major restrictions for the number of Charging Poles is the range of the communication technology used for the last mile communications. For that reason, the Concentrators may cover limited distances of about 1 or 2 km. In rural areas, the small number of Charging Poles that can be covered by this distance is one of the main reasons why the use of concentrators could not be the most suitable communication architecture in these cases.

For the last mile, a number of technologies are currently available and under continuous development. These technologies are analysed in D4.1, and depending on different aspects, several options can be considered to implement these last mile communications. Some of the available technologies are GPRS, 3G/UMTS, ADSL, FTTH/GPON, Hybrid Fiber-Coax, Zigbee, WiMAX or Broadband over PLC.

In urban areas with a high density of Charging Poles, a combination of PLC for the last mile and GPRS or UMTS for the upstream communications could be the most recommended solution. Power Line Communications (PLC) consists in a high frequency communication technology that uses the existing electric grid and allows Throughput up to 1.5 Mbit/s, and communication ranges up to 1 km (enough for the communication between the Charging Pole and the Concentrator). In that case, the concentrator could be placed on MV/LV substations, which could solve two of the main disadvantages of PLC; the impossibility of communication across transformers and the problems experienced in the use of PLC in MV grids. The use of PLC only in the LV grid could reduce the infrastructure investments considerably, as it does not need to communicate across transformers because it uses a grid with a unique voltage level.

As an alternative to PLC, Ethernet through fiber optic cable is proposed in downstream communications of the Concentrator. This technology offers high transmission rates and high capacity to send data, but the investment needed for the installation of a new fiber optic communication grid is too high. For that reason, it only becomes a realistic alternative when this infrastructure is already present. Other wired technologies such as CAN-bus or PWM are not suitable here, and wireless technologies such as Zigbee or Bluetooth are dismissed for several reasons. Firstly, all its transmission ranges are much lower than the recommended ones and, secondly, these technologies require higher investments in the installation of the required devices.

However, the PLC technology is not as suitable for upstream Concentrator communications as it is for the downstream ones. Then, protocol communications used downstream Concentrator interface may be different from those used on upstream Concentrator interfaces. In contrast with the downstream communication of the Concentrator, for the upstream communications the distance between the agents could reach high distances and installing new infrastructure to establish the communications could increase considerably the costs. Wireless technologies such as GPRS, UMTS or Wi-MAX or wired technologies such as Ethernet are the most feasible alternatives in upstream communications of the Concentrator. They meet the ICT requirements and in addition, in some cases, will be possible use already mounted infrastructures of communications.

As said in D4.1, it makes economic and technical sense for the Aggregator/Retailer to use ISPs telecommunications services to reach the concentrators. ISPs have well defined products for enterprises with these types of needs, which normally also include additional services on top of pure connectivity, like virtual private networks, security, quality of service, etc. The ISPs structure has resources, both machine and human, which are shared by all the services provided by them to their

customers and will more than likely be able to provide a cheaper and better service, than if the Aggregator/retailer would do it itself. In addition, the collection of data from several Charging Poles using concentrators could minimize the number of endpoints that need to transmit information, which could considerably reduce the number or communication end points that need to be contracted.

In some situations in the advanced world, the Aggregator could also try to develop synergies with the customer, and take advantage of an existing internet connection and use it as the connection path to reach the customer. This is particularly the case for good internet connection and Triple Play services, where the Aggregator traffic would not impact the available throughput of the customer, who also does not pay by Mb but rather a fixed monthly fee, which he will maintain regardless of the Aggregator activities. The Aggregator service can also be seen as an advantage for the customer, and then ISPs could see an advantage of providing them very good conditions for accessing the customer on triple play products. These synergies could significantly reduce the operational costs of performing the aggregation function, as it does not need to invest in new communication infrastructures.

More so is the case if specialized ISPs are used, as is the case of DSOs Smart grids, as a platform for reaching the customer location. DSOs smart grids are supported on a communications platform, which can be self-operated (likely when talking about a PLC supported smart grid) or in its turn subcontracted to an ISP (for example smart grids supported on GPRS). In a similar way, the AMM communication infrastructure such as concentrators can be also used for the EV communications if an agreement can be achieved between the involved actors.

## 6 ICT infrastructure cost analysis

The cost of the recommended ICT technologies for each scenario will be assessed based on previous experiences on deployment ICT infrastructure in power systems around the world, since experiences with electric vehicles are very limited. Moreover, the operation costs are also difficult to assess as such cost for each country differs.

### 6.1 ICT infrastructure

The aim of this section is to realise a benchmarking on the telecommunications infrastructure for the deployment of the electric vehicle. Then, a bibliography search on smart metering projects has been realised. Among the different reports that have been found, the following documents are selected as references and have been analysed:

- Assessment of Plug-in Electric Integration with ISO/RTO Systems [13]
- Smart metering & Infrastructure Program Business Case [14]
- Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism. Volume 1 – Business Vision, Management Philosophy, and Summary of Business Case Analysis [15]

The document “Assessment of Plug-in Electric Integration with ISO/RTO Systems” has been done by KEMA for the ISO/RTO Council. Published in March 2010, this document deals with the electric vehicle integration in North America. KEMA has evaluated the incremental costs to integrate plug-in electric vehicles into existing ISO/RTO systems. The infrastructure analysed would support up to 250 PEV Aggregators, which each one would likely support 800 to 1000 end-point devices, which in that case correspond to EV Charging Poles.

The report “Smart metering & Infrastructure Program Business Case” has been realised by BC Hydro Company in 2010. This paper deals with the implementation of a Smart Metering program in Ontario (Canada), which involves the replacement of 1,8 million existing customer meters with a comprehensive smart metering system, including the technology and telecommunications infrastructure needed for BC Hydro.

The Volume 1 of the document “Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism” has been done by Southern California Edison Company in 2005. This company has completed a rigorous business case analysis of Advanced Metering Infrastructure (AMI) in California. The document sets forth a summary of the costs for two different scenarios: full deployment and partial deployment scenarios. Full deployment scenario consists of replacing 4,5 million existing meters by smart meters, whereas partial deployment implies only the replacement of 325.000 meters.

Table 17 shows a summary of the main data from such documents, containing the author, the publication date and the scope of the different initiatives. In addition, the number of end-point devices or smart meters to be installed is detailed, which will be the base to compare the costs of the different projects.

**Table 17. Summary of document data.**

<b>Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems</b>	<b>Smart Metering &amp; Infrastructure Program Business Case</b>	<b>Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism</b>
<b>Document data</b> Date publication: March 2010 Produced by KEMA for the ISO/RTO Council in conjunction with Taratec Funded by the ISO/RTO Council (IRC) Scope: North America (Canada and United States)	<b>Document data</b> Date: 2010 Company: BC Hydro Scope: Ontario (Canada)	<b>Document data</b> March 2005 Realised by Southern California Edison Company Scope: California (United States)
<b>Comparison base</b>		
250 PEV Aggregators with 800 to 1.000 end-point devices each Aggregator	1,8 million smart meters	4,5 million AMI meters (full deployment) or 325.000 AMI meters (partial deployment)

### 6.1.1 Comparison of infrastructure investment

In this section, the costs for infrastructure investment are detailed and compared for each document. Two considerations have to be taken into account: the used currency (supposed to be US dollars) and the publication date (2010 and 2005). The difference between the publication dates could cause variations in the cost assessment due to the inflation and technological improvements.

- **Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems**

In this study, incremental costs to integrate Plug-in Electric Vehicles resources into existing ISO/RTO systems are calculated. The total infrastructure fixed costs will range between \$17.580.000 and \$17.845.000, with a cost between \$70 and \$90 per end-point. Instead, the total annual costs will range between \$155.760 and \$774.960 with a cost of \$0,62 to \$3,87 per meter. This infrastructure would support up to 250 PEV Aggregators with 800 to 1.000 end-point devices each Aggregator.

- **Smart Metering & Infrastructure Program Business Case**

According to BC Hydro estimation, the total amount for the Smart Metering Program will be \$930 million (nominal value)<sup>5</sup>. The costs of initiation, identification and definition phase are estimated to be around \$40 million, representing a 5% of the \$930 million. Implementation phase amounts approximately \$720 million (77% of total costs). Interest during construction, contingency and reserve subject to board control add \$165 million, representing an 18% of the total cost.

However, the implementation phase (approximately \$720 million) has only been considered in this benchmarking, involving a cost per meter around \$400.

- **Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism**

Finally, regarding Southern California Edison Company, full deployment (installation of 4,5 million AMI meters) is estimated at \$1.298,4 million, whereas partial deployment (325.000 smart meters) at \$168,2 million. The cost analysis includes costs of meter and installation, communication system, IT, customer services and management and miscellanea. This result implies a cost per meter of approximately \$290 (full deployment) or \$520 (partial deployment).

<sup>5</sup> The document does not specify the currency which is supposed to be US dollars.

Table 18 shows a comparison of infrastructure costs, including the number of smart meters or end-points to be installed, the total costs and the cost per meter.

**Table 18. Total costs and costs per meter or end-point for each project.**

Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems	Smart Metering & Infrastructure Program Business Case	Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism
250 PEV Aggregators with 800 to 1.000 end-point devices each Aggregator	1,8 million smart meters	4,5 million AMI meters (full deployment) or 325.000 AMI meters (partial deployment)
<b>Total costs</b>		
Fixed Costs: \$17,6 to \$17,8 million Variable Costs (annual): \$155.760 to \$774.960	\$716,5 million	Full deployment: \$1.298,4 million Partial deployment: \$168,2 million
<b>Cost per meter/end-point</b>		
Fixed costs: between \$70 and \$90 per end-point Annual cost: \$0 ,62 to \$3,87 per end-point	\$400 per meter	Full deployment: \$290 per meter Partial deployment: \$520 per meter

### 6.1.2 Comparison of broken down infrastructure costs

Next tables show a comparison of the telecommunications infrastructure broken down costs regarding the following items: smart metering system, telecommunication and network infrastructure, management costs, variable and miscellaneous.

Firstly, the smart metering costs are shown in Table 19. KEMA does not include the investment for the smart metering system, which is evaluated in the two other projects. Smart metering implementation supposes between \$150 and \$220 per meter. Both projects consider the smart meters, the installation and the deployment activities. However, telecommunications and software costs are included in Ontario's project, which is not taken into account in California's project that will be considered in network infrastructure costs.

**Table 19. Smart metering system implementation costs**

Smart Metering & Infrastructure Program Business Case		Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism		
1,8 million smart meters		4,5 million AMI meters (full deployment) or 325.000 AMI meters (partial deployment)		
Smart Metering System: - Architecture and Design; - Smart meters, Telecommunications, Software; - Deployment Activities	\$391,1 million	Meter System and Installation Costs: - Meter procurement - Supply chain management - Testing - Installation - Associated support activities	Full deployment \$668.399.000	Partial deployment \$60.063.000
<b>Total</b>	<b>\$391,1 million</b>	<b>Total</b>	<b>\$668.399.000</b>	<b>\$60.063.000</b>
<b>Cost per meter</b>	<b>\$217,28</b>	<b>Cost per meter</b>	<b>\$148,53</b>	<b>\$184,81</b>



Project management investment for each project is shown in Table 20. The project management costs have been compared, resulting in a cost per meter between \$15 and \$90.

KEMA includes ISO/RTO reliability-related and Aggregator project management investments; however the contents of these items are not detailed.

Both projects, in Ontario and California, include project management costs, as well as finance activities; specifically in California contingencies are contained in the analysis of the costs. In addition, both consider customer research or acquisition and contract management. Activities on safety, security, privacy or governance are included in Ontario’s project, but probably not in California’s project. Instead, employee communications and training costs are included by Southern Edison Company, as well as other miscellaneous start-up related costs.

**Table 20. Project management costs**

Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems		Smart Metering & Infrastructure Program Business Case		Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism		
200.000 to 250.000 end-points devices		1,8 million smart meters		4,5 million AMI meters (full deployment) or 325.000 AMI meters (partial deployment)		
Project management		Program Delivery Activities				
ISO/RTO Reliability-Related Investments	\$15.000	<ul style="list-style-type: none"> <li>- Project Management and Controls;</li> <li>- Safety, Security, Privacy Governance;</li> <li>- Finance and Regulatory;</li> <li>- Customer Research, Engagement and Outreach;</li> <li>- Contract Management</li> </ul>	\$37 million		Full deployment	Partial deployment
Aggregator investments	\$5.000.000			Management and other Costs	\$170.578.000	\$29.021.000
<b>Total</b>	<b>\$5.015.000</b>	<b>Total</b>	<b>\$37 million</b>	<b>Total</b>	<b>\$170.578.000</b>	<b>\$29.021.000</b>
<b>Cost per end-point</b>	<b>\$20 – \$15</b>	<b>Cost per meter</b>	<b>\$20,56</b>	<b>Cost per meter</b>	<b>\$37,91</b>	<b>\$89,30</b>

Investments on network infrastructure are analysed and compared in Table 21, resulting in \$50 to \$160 per meter.

This item contains the costs for information technology, as well as ICT grid modernization infrastructure upgrades. In the cases of Ontario and California, the information technology activities involve the applications and computer services necessary to support AMI that is meter installation and reading applications and data management systems. Infrastructure upgrades involve servers, advanced telecom devices and applications and the required activities. KEMA divides the costs in two sections, one related to ISO/RTO systems investments and the other to aggregator investments, including the servers, the network infrastructure, the SCADA link engineering for both sections. Southern Edison Company also considers security systems that are included in California in the program delivery activities which contain project management.

**Table 21. Network Infrastructure costs**

Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems		Smart Metering & Infrastructure Program Business Case		Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism		
200.000 to 250.000 end-points devices		1,8 million smart meters		4,5 million AMI meters (full deployment) or 325.000 AMI meters (partial deployment)		
Incremental fixed costs					Full deployment	Partial deployment
Systems update to support PEV Aggregators	<b>0 - \$265.000</b>	Solution Integration (Information Technology): - Architecture and Design; - Meter Data - Management System and Other Applications; - Implementation Activities	\$60,9 million	Information Technology Costs	\$205.352.000	\$45.437.000
ISO/RTO Reliability - Related Investments: - servers, - network infrastructure, - SCADA link engineering - Upstream impacts on EMS	<b>\$65.000</b>					
Aggregator Investments: - server, - network infrastructure, - SCADA software, - engineering	<b>\$12.500.000</b>					
<b>Total</b>	<b>\$12.565.000 – \$12.830.000</b>	<b>Total</b>	<b>\$115,1 million</b>	<b>Total</b>	<b>\$245.365.000</b>	<b>\$51.920.000</b>
<b>Cost per end-point</b>	<b>\$50 - \$64</b>	<b>Cost per meter</b>	<b>\$63,94</b>	<b>Cost per meter</b>	<b>\$54,53</b>	<b>\$159,75</b>

Variable annual costs are only considered in KEMA's analysis, which are related to EV Aggregators staff labour and secure communications. Shown in Table 22, these costs amount \$0,62 to \$3,87 per end-point device.

Regarding operation cost of communications, an ISDN is estimated between \$4.800 and \$24.000 per year (\$400 to \$20.000 per month), and ISP over internet in \$960 per year (\$80/month).

**Table 22. Variable costs**

Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems	
Variable costs (annual costs)	
- Annual staff labour costs of PEV Aggregators	\$150.000 - \$750.000
- Secure communications	\$5.760 - \$24.960
<b>Total</b>	<b>\$155.760 - \$774.960</b>
<b>Cost per end-point</b>	<b>\$0,62 - \$3,87</b>

Finally, miscellaneous costs from Ontario and California's projects are detailed in Table 23. The deployment of 1,8 million smart meters in Ontario involves other costs as theft detection and conservation tools, which will be around \$90 per meter. Instead, the customer services required by the AMI infrastructure in California will be estimated between \$47 and \$70 per meter. The customer service systems category contains billing, call centre, meter order processing and customer communications (marketing) activities.

**Table 23. Miscellaneous costs**

Smart Metering & Infrastructure Program Business Case		Testimony Supporting Application for Approval of Advanced Metering Infrastructure Deployment Strategy and Cost Recovery Mechanism		
<b>Other costs</b>		<b>Other costs</b>		
Theft Detection: - Architecture and Design; - Distribution System Meters, Application software; - Deployment Activities	\$110,5 million	Customer Services Costs	\$211.459.000	\$23.122.000
<b>Cost per meter</b>	<b>\$61,39</b>	<b>Cost per meter</b>	<b>\$46,99</b>	<b>\$71,14</b>
Conservation Tools: - Architecture and Design; In- Home Displays, Website, Software Supporting rates; - Rebate program				
<b>Cost per meter</b>	<b>\$34,89</b>			

## 6.2 Operation cost

As said before, regarding the operation cost of communications, in KEMA's analysis the cost of an ISDN is estimated between \$4.800 and \$24.000 per year (\$400 to \$2.000 per month), and ISP over internet in \$960 per year (\$80/month).

**Such data can be compared with the data from a report of the European Commission for Broadband Internet Access tariffs that are shown in Figure 3 and**

Figure 4 [16]. According to this report, Broadband Internet Access is defined as an access assuring an always-on service with speeds in excess of 144 kbps. The study presents the least cost of one ISP per each country for different transmission rates (from 144 kbps to 20 (or more) Mbps). The study covers 33 countries: the 27 Member States of the EU, Norway, Iceland, Japan, South Korea, Canada and three different States of the USA (New York, California and Colorado).

The obtained cost per month can be summarized in Table 24.

**Table 24. Summarized costs versus transmission rate**

Transmission rate	Range (€/month)
114-512 kbps	10-30
512-1.024 kbps	15-40
1.024-2.048 kbps	20-40
2.048-4.096 kbps	20-50
4.096-8.192 kbps	25-60
8.192-20.000 kbps	25-60
> 20 Mbps	30-70

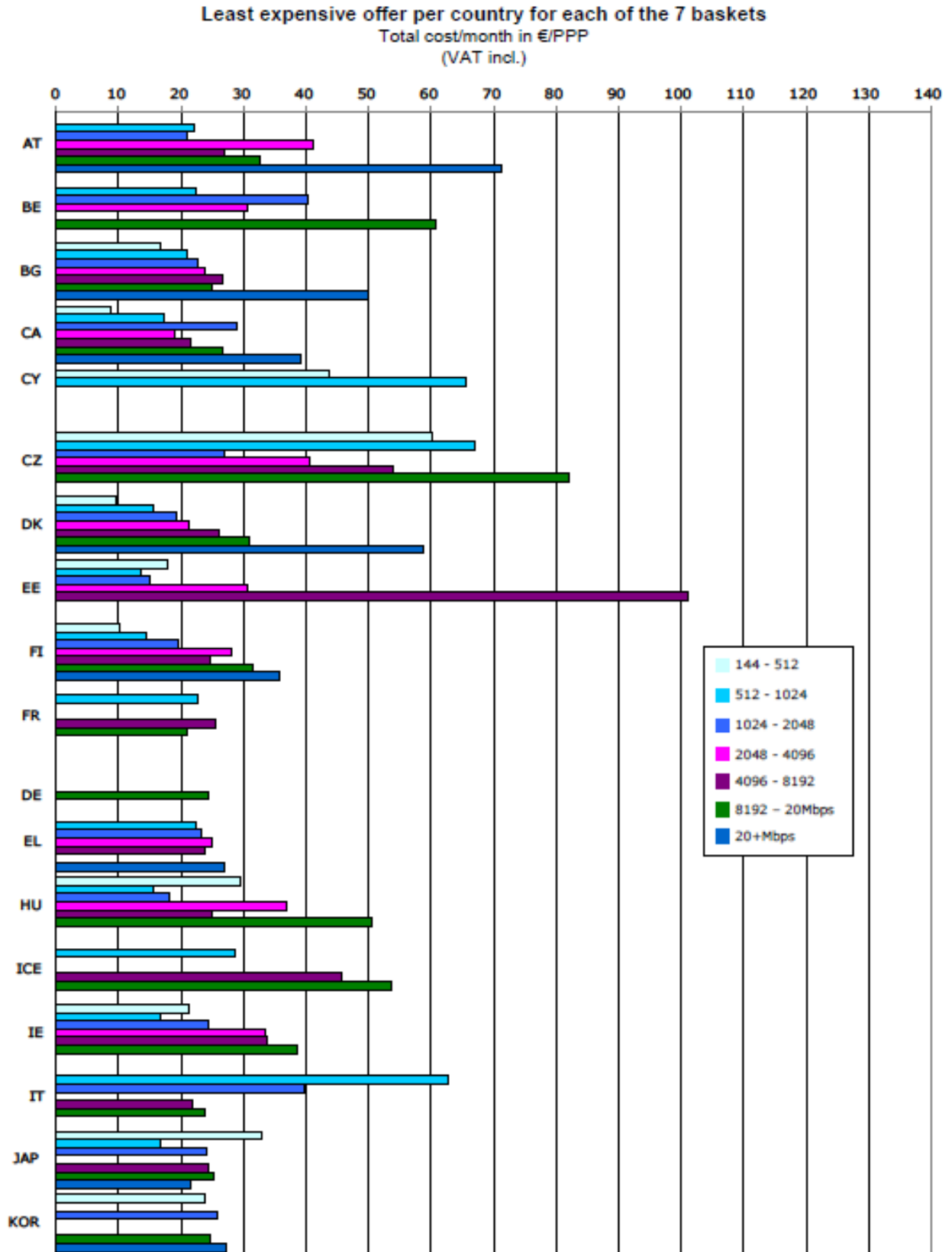


Figure 3: Least expensive offer per country for broadband internet access cost [16] (1/2)

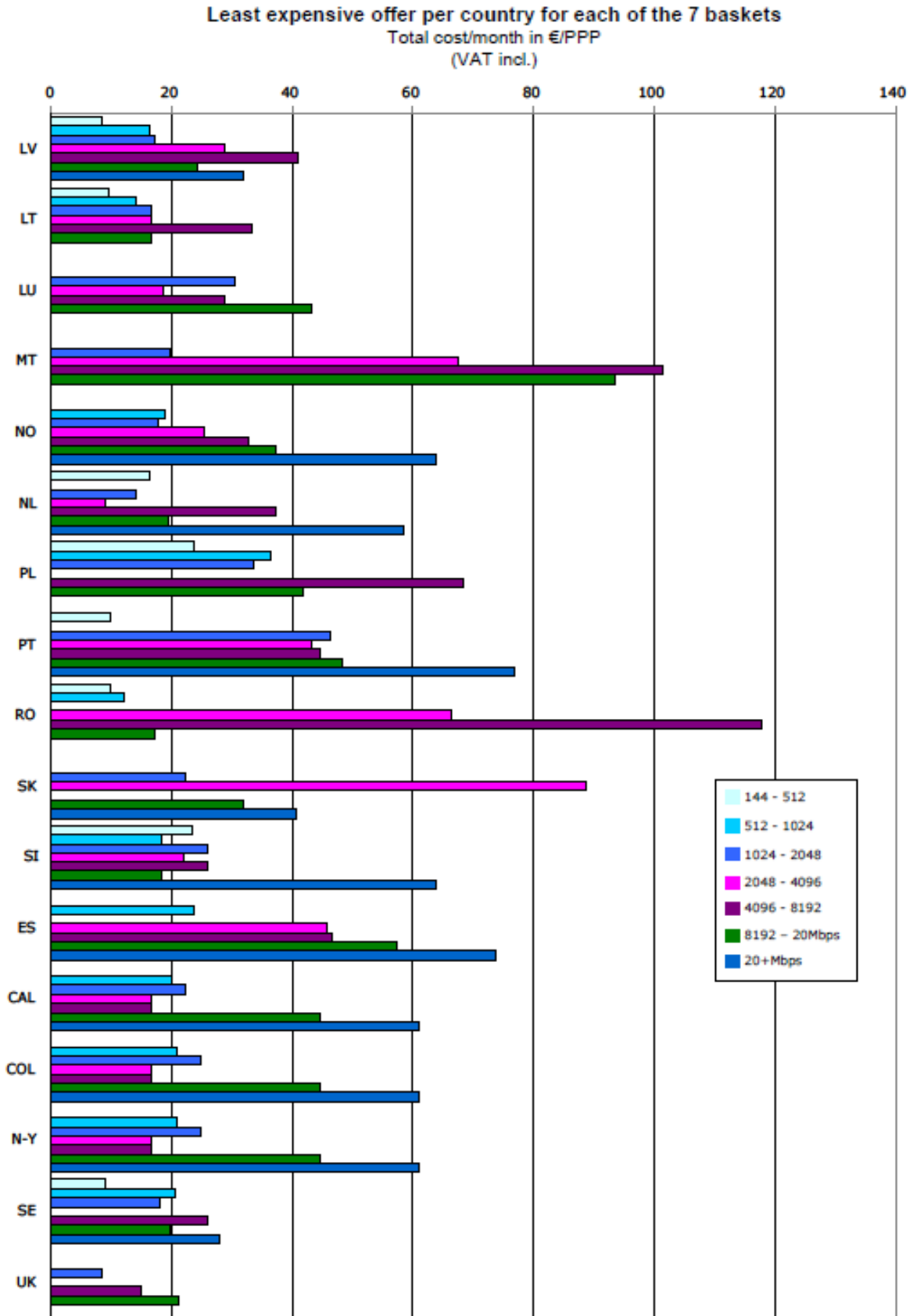


Figure 4: Least expensive offer per country for broadband internet access cost [16] (2/2)

### 6.3 Summary of costs

Once described the main issues in several projects regarding smart metering and electric vehicles, this chapter summarizes these ICT costs. As studied projects are from North America, a currency conversion has been done. The conversion rate is assumed to be 1,35 € per \$1.

In previous sections, the ICT costs have been divided into infrastructure and operation costs. Infrastructure costs are considered per meter, whereas the operation costs are variable cost per month depending on the transmission rate used.

The infrastructure costs are divided into network infrastructure, smart meter and other costs. Network infrastructure costs include utility investments in order to upgrade the existing ICT infrastructure. It varies between \$50 and \$65 per end-point, which correspond to 37 € and 48 €. Another cost included in the infrastructure cost is the smart meter. Its costs range between \$150 and \$217 per meter, which correspond to 110 € and 160 €. According to EC road map [17], it can be assumed that smart meters should be operational when the full deployment of EV occurs. However, in some cases a meter dedicated to the Charging Pole (downstream the meter installed at the point of delivery) could be required due to EV specific requirements, different taxes for the energy consumption of EV, etc. Finally, in other costs, the management and deployment of the project are considered, as well as other miscellaneous start-up related costs. Other costs vary between \$90 and \$115 per end-point, which correspond to 65 € and 85 €. Taking into account the complexity of the ICT infrastructure required in each scenario, estimations of the investment needed have been done.

For the operation cost, the ICT requirements have been used to estimate the transmission rates for the upstream communications needed in each scenario. Then, these transmissions rates are compared with the costs exposed in Table 24 in order to obtain the ISP monthly cost per concentrator in each scenario.

All these costs are only referred to *Upstream communications of the Charging Pole*, as the ICT costs regarding *Customer ID communications* and the *Electric Vehicle to Charging Pole communications* are considered to be included in the Charging Pole station.

In Table 25 an estimation of ICT costs is done for each scenario world, taking into account the requirements defined in previous sections.

**Table 25. Summary of ICT cost for each scenario world**

	Scenario worlds		
	Conservative	Pragmatic	Advanced
<b>Infrastructure costs</b>			
ICT Network infrastructure (€/end-point)	0 - 40	0 - 50	40 - 50
Smart meter (€/end-point)	0 - 110	110 - 160	110 - 160
Other costs: management, deployment... (€/end-point)	0 - 65	65 - 85	65 - 85
<b>Operation costs per concentrator</b>			
Broadband Internet Access (€/month/concentrator)	20 - 50	25 - 60	30 - 70

Due to the nature of the input parameters (estimations) the results obtained from the technical and economical calculations can be considered as trendsetting. However, the calculations that acted as the basis for the comparisons can be used in the adjustment of the results when more accurate input data will be available.

## 7 Conclusions

The overall objective of this report is to define and summarize the ICT requirements and then get recommendations for the ICT solutions for the electric vehicles infrastructures. The stakeholders involved and the communications processes have been defined in previous deliverables so this report has been only focused on ICT requirements and recommendations. To do this, firstly it has been discussed a review of proposed technologies in order to summarize their main features. Afterwards, the main features for the evaluation criteria have been defined in order to evaluate the ICT requirements and needs for the electric vehicle processes. Then, the most adequate technologies regarding the defined requirements have been recommended. Finally, the cost of these recommended ICT technologies have been assessed.

As has been seen, many stakeholders with different needs of communication are involved. With the objective of making the recommendations more comfortable, three communication paths have been defined: Customer ID communications, Electric Vehicle to Charging Pole communications and upstream communications of the Charging Pole. The requirements of each of these processes have been studied for each one of the scenario worlds. Thus, after studying and analysing the communication flows and their requirements, the ICT recommendations are:

- **Customer ID communications:** RFID is a suitable technology for the ID process because, as have been studied above, it is secure, reliable and cost-effective. RFID communications will improve to NFC, which should be most adequate in advanced scenario world when this technology becomes more consolidated. When more complex services are required, the use of Smart Cards is an alternative that should be taken into account. However, they are more expensive, what could difficult their implantation, in particular when comparing them with RFID. Other proposed technologies such as PLC, Zigbee, UMTS, etc. have been discarded because they are more appropriate in other kind of applications than in the identification of the user's vehicle. Regardless of the scenario world, it also needs to be considered that in some situations such as in private charging, the ID process can be avoided as the user is always the same.
- **Electric Vehicle to Charging Pole communications:** According to the requirements defined, CAN-bus should be an appropriate technology in this process. It has adequate features and is used in automation industry already. Also PLC is a favourable method, but it needs a higher investment. Maybe they should be used in the more complex scenario worlds. In contrast, PWM is an appropriate technology to be used only when basic communications are needed, such as in conservative world. In this communication process, wireless technologies have been discarded, because they are most appropriate in long range data transmissions.
- **Upstream communications of the Charging Pole:** In this communication flow, several technologies can be installed such as Ethernet, GPRS, UMTS or Wi-MAX. However, due to the complexity of proposed architecture, a Concentrator device should be installed between Charging Poles and the upstream stakeholders in dense urban areas. Then, between the Concentrator and the Charging Poles it should be recommended the use of PLC technology. However, this technology should not be suitable for upstream communications due to the existing transformers in the MV/LV substations. Then, the communication method used for the upstream Concentrator interface should be different. In that sense, wireless communications (such as GPRS, UMTS or Wi-MAX) or using an already existing infrastructure (Ethernet, FTTH or copper) are the most feasible alternatives in upstream communications of the Concentrator. In case that the Concentrator is not used (like in non-dense areas), wireless communications (such as GPRS or UMTS) or wired infrastructures (Ethernet over FTTH or existing PSTN copper wires) are the most feasible alternatives to directly connect Charging Poles with the upstream stakeholders.

Initially, the power exchange process and the billing process use two separate communication channels to perform their functionalities. They have similar ICT requirements, and both have to communicate the Charging Pole with the rest of upstream actors. For that reason, the use of the same communication infrastructure is highly recommended when some kind of agreement can be achieved between the owners of this two communication interfaces. Then, the communication interfaces can remain separately by the use of virtual private networks over the same communication path.

Regarding those upstream communications, it is highly recommended that ISPs telecommunications services are used to reach the concentrators or Charging Poles. The great investment needed to create a completely new communication infrastructure causes that the ISPs structure provide a cheaper and better service. When an internet connection is present, the Aggregator could also try to take advantage of this existing connection and use it as the connection path. In future scenarios, other specialized ISPs like DSOs Smart grids will be also used in the electrical grid. When it will be possible, this platform should be used for reaching the customer location. DSOs smart grids will be supported on a communications platform, which can be self-operated or in its turn subcontracted to an ISP.

Finally, the cost of ICT technologies is assessed. On one hand, a benchmarking on smart metering and electric vehicle projects has been done in order to obtain the broken down costs regarding network infrastructure, smart metering and miscellaneous costs. On the other hand, the least cost of one ISP per each country for different transmission rates has been identified for estimating the operation cost. Such data has been used to estimate the cost of ICT infrastructure in the different scenario worlds.

## 8 Future research topics

This report offers a wide overview of the ICT infrastructure trends for the deployment of electric vehicle. The open issues that have been identified for further research within the WP4 are listed next:

- Identification of user by the use of biometrics methods: fingerprint, palm print, iris recognition, etc. Security of data is a main concern if considering these methods.
- Identification at the same time of the EV user and the EV through the vehicle intelligence.
- The introduction of communicating meters has led to strong privacy concerns which have delayed and in some cases hindered their introduction. These concerns should be solved in order to ensure privacy in this kind of communications.
- The speed of change in digital communications is most prominently represented by broadband wireless access and home networking technologies. On one hand, progresses in wireless technologies can offer new and better option for Last Mile stage. On the other, Home Area Networks (HAN) are being deployment by incorporating to the whole set of domestic appliances. If an electric vehicle is plugged in a house with a HAN, the interaction with such network has to be considered.
- Smart grid topics such as a smart metering, demand response or distribution automation, need the deployment of new communication infrastructure in order to deal with these new challenges in the electric sector. The possibilities of integration those smart grid ICT infrastructures with the networks to address EV need to be studied.
- In order to save on the deployment of a communications network for billing, integrating this system with the control communications in real time should be studied. In a similar way, the possibility that both interfaces could share the same physical communication path should be considered.
- Standardization processes are basic to achieve interoperability. For that reason, ID technologies and communications between the EV and the charging infrastructure need to be standardised to ensure that these processes are independent of the owner of the pole, and of the energy supplier within Europe. In that sense, standardization needs to be accelerated before the massive deployment of EV becomes a reality.
- For the anticipated large scale roll-out of electric vehicles, an early agreement on international standards in the ICT interfaces is as essential as the standardisation of physical interfaces like interconnectors. Therefore initiatives on standardised data objects and communication protocols with respect to electric vehicles billing should be achieved.

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## 10 Glossary

- **ID:** identification
- **RFID:** radio-frequency identification
- **NFC:** near field communication
- **PLC:** power line communications
- **GPRS:** general packet radio services
- **GSM:** global system for mobile communications (2G)
- **UMTS:** universal mobile telecommunications system (3G).
- **FTTH:** fiber to the home
- **PSTN:** public switched telephone network
- **ADSL:** asymmetric digital subscriber line
- **ISP:** internet service provider
- **EVSE:** electrical vehicle supply equipment
- **ISDN:** integrated services digital network