Strategic Manual for EV charger installations

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Summary

The strategical manual is a tool to help municipalities, without deep knowledge on charging infrastructures, during the installation of electric vehicle (EV) chargers.

The strategic manual is divided in four chapters, each one described with different steps to be followed during the charger installation:

- The *preparation work* guides the user from the initial idea of installing a charger, considering site location evaluation, charger size, expenses.
- The *on-site evaluation* guides the user on deeper and final characterization of site location and charger size. This chapter mainly focuses on national and local guidelines, space selection, such as visibility, accessibility, proximity to power source, etc..
- The *installation* chapter is a checklist to follow during the installation. This should be used when charger and location are settled and the manual user has all the permits for the installation (including engineering and economic calculations).
- The *maintenance* chapter gives an idea of which kind of works have to be considered during the lifetime of a charger and as a consequence the correlated costs to the charger during its lifetime.

Finally, the manual presents the three main topics that drive the decision making and the risk analysis for the charger investment: economic feasibility, technical feasibility and customer acceptance. This tool presents the main guidelines and frequently asked questions to be considered during the analysis.

Technical requirements differ from country to country and partly from company to company so technical solutions do also. The report does not assess whether a solution is “better” or “worse” than another, but identifies the topics which are important to be taken into consideration when dealing with charging infrastructure.

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Process checklist

	ACTION	RESPONSIBLE	
STEP 1: Prep work	1. Decision made to install charging station: location, target users	Parking Owner and possible parts involved	☐
	2. Determine number and characteristics of charging stations	Owner	☐
	3. First economic expenses	Owner	☐
STEP 2: On-site evaluation	4. Location survey complete and parking space selected	Owner/Contractor	☐
	5. Necessary level of power source	Owner/Utility	☐
	6. Installation estimate made	Contractor	☐
	7. Need for electrical upgrade determined	Contractor/Utility	☐
	8. Estimate approved/accepted	Owner/Contractor	☐
	9. Economic business model	Owner	☐
	10. Customer acceptance verified	Customers/society	☐
STEP 3: Installation	11. Permit application field	Contractor	☐
	12. Electrical upgrade, if required	Utility/contractor	☐
	13. Charger installation and connection	Contractor	☐
	14. Inspection	Inspector	☐
	15. Final economic model	Owner	☐
	16. Work completed/Performance verified	Contractor	☐
STEP 4: Maintenance	17. Servicing and Maintenance	Owner	☐

STEP 1: Prep work

Site selection evaluation:

a. Analyze geographic area and DSO infrastructure
b. Analyze travel patterns and parking habits
c. Define the geographic coverage
d. Determine the number of EVs and population range present in the area
e. Analyze the chargers already present in the area

Further criteria (Yunna Wu, 2017):

Criteria	Sub-criteria
Economy	a. Construction cost b. Annual operation and maintenance cost c. Investment payoff period
Social	a. Service capability b. Improvement of employment c. Promotion of EVs potential
Environmental	a. Fine particles emission reduction b. Destruction degree on ecological environment
Planning	a. Proximity to substation b. Influence on the power grid c. Accessibility of site d. Available land resources e. Possibility of capacity expansion in future
Residential community	a. Per capita EV ownership b. Average income level of residents c. Residents´ acceptance

Survey for electric vehicle owners

Survey for electric vehicle owners to understand which are the user needs (https://www.surveymonkey.com/r/RNNBRVL, https://www.ausnetservices.com.au/Misc-Pages/Electric-Vehicle-Owners-Survey):

1. Are you male/female?
2. Age range: (21-30, 31-39, 40-49, 50-59, 60-60, 70 or older)
3. Which of the following would match your current job position:
   - Senior management
   - Middle management
   - Executive level
   - Retires
4. In which country do you live?
5. Where do you live?
   - City
   - Country
   - Commuter belt
6. How many km per day do you typically drive you electric vehicle?
   - 0-20 km
   - 21-40 km
   - 41-60 km
   - 61-80 km
   - 81-100 km
   - 101-150 km
   - More than 150 km
7. Do you sometimes use your EV to drive longer distances? If yes, which range of distances?
8. Do you have a home charger? Yes/no. If yes, which level is it?
9. What percentage of your charging is done at home?
   - 25%
   - 50%
   - 75%
   - 100%
   - None
10. How many times per month do you charge outside your home?
11. What time do you usually charge at home?
   - As soon as I get home
   - Overnight during off-peak times
   - Other: provide details
12. What percentage of your charging is done using slow charge points (less than 3.7 kW)?
   - 25%
   - 50%
   - 75%
   - 100%

- None

13. Where would you like to see more public charge points?
14. Which is the most important factor affecting your decision to purchase an EV? (capital cost, running cost, driving range of the vehicle, access to charge point, environmental benefits, vehicle size etc..)
15. What helped you to make that final decision to purchase an electric vehicle?
16. How many vehicles do you own? Specify the type: combustion, electric, hybrid.
17. How would you rate the public charging network in your area? Where 1 is the lowest rating and 10 is the highest.
18. Do you think the existing charging infrastructure could be improved? Yes/no, if yes how could it be improved?
19. How do you think electric vehicles could be promoted better to the general public?

During the preparation work it is important to investigate and define who will own and who will pay for the charger and for the land/parking space:

	WHO OWNS	WHO PAYS
CHARGER		
LAND/PARKING SPACE		

Pay attention that different owners/payers could differently impact on the chargers decision makings!

→ Define installation location of the charger infrastructure based on the above analyses:

i. Private ii. Mixed-use (private/public) iii. Workplace

iv. Long-term parking v. Retail vi. Public

→ Target group of users to serve:

i. Personal ii. Fleet iii. Employee

iv. Customer v. Visitor

→ Charging station infrastructure model:_____

→ Charging purpose:

i. Destination (slow charging) ii. "En route"- on the way (fast charging)

Mode:____

Mode	Description	Phase	Maximum current	Maximum voltage
Mode 1 (AC)*	home charging from a standard power outlet without any safety measures	1	16 A	250 V
		3	16 A	480 V
Mode 2 (AC)	home charging from a standard power outlet with an in-cable EVSE supplied with the EV	1	32 A	250 V
		3	32 A	480 V
Mode 3 (AC)	wired-in AC charging station	1	32 A	250 V
		3	250 A	690 V
Mode 4 (DC)	wired-in DC charging station	-	400 A	600 V

* prohibited in the US by national codes

Level	AC	DC
Level 1	1.4 kW (12 A, 120 V) 1.9 kW (16 A, 120 V)	up to 36 kW (80 A, 200-450 V)
Level 2	2.4 kW (10 A, 240 V) 3.8 kW (16 A, 240 V) 7.7 kW (32 A, 240 V) 19.2 kW (80 A, 240 V)	up to 90 kW (200 A, 200-450 V)
Level 3*	>19.2 kW	up to 240 kW (400 A, 200-600 V)

* proposed values, standard ones yet to be defined

For more info about mode and type refer to (Knezovic, 2017)

Type:_____

Currently available charging points (Spöttle, 2018):

TYPE	POWER OUTPUT	KILOMETRES PER 10 MINUTES OF CHARGE	TYPICAL LOCATIONS	COST FOR A SINGLE CHARGING POINT*
AC Mode 2 Home	up to 11kW	1-2	Home	< Euro (EUR) 800
AC Mode 2 Commercial	up to 19.4kW	3.2	Private, Workplace, and Public	<EUR 2,000
AC Mode 3 Fast Charging	22kW or 43kW	21	Public, Private	EUR 1,000-4,000
DC fast charging (standard)	20-50kW	64	Public, Private	EUR 20,000
DC high power fast charging	100-400kW	90	Public	EUR 40,000-60,000

*Note: this is only the purchase cost of the charger itself, not the installation, grid connection or operational costs.

→Number of charging stations____ and points____ to be installed.

→ Physical Dimensions:

Height:_____ Width:_____ Depth:_____

Base Dimensions:_____ Cord length:_____

Even though the manual is a guideline for installing EV chargers, it is important to consider the local energy system that will surround the charger infrastructure. The transportation electrification must be (as much as possible) environmentally sustainable, and to do so the electricity used by the EV chargers must be renewable. Here there are some questions that can be investigated when installing a charger infrastructure:

1. Is there locally produced renewable energy around the area of installation? Could this energy be coupled with the charger infrastructure in order to minimize the power needed from the grid?
2. Is it possible to shift the electrical loads from the charging infrastructure in time, to minimize the power needed from the grid?
3. Is it possible to shift other electrical loads such as for heating/cooling or ventilation in time, to minimize the power needed from the grid?
4. Is it possible to have a common electricity contract?

→ Charging infrastructure expense:_____

Local energy system

(The expenses have to be shortly investigated considering costs and benefits listed in the "Economic feasibility")

What is the size of the electrical service to the site?_____

→ Aimed power source:_____

The customer must provide the ownership or an approval of using the power source. Contact the utility if a service upgrade is needed.

It is important to:

1. Contact the local utility to inform that vehicle charging infrastructure will be installed at the site, if grid reinforcements are necessary and to get the permit for installation and inspection of charging stations

2. Engineering calculations: depending on the location and charging infrastructure engineering calculation could be needed to avoid grid issues and failures.

STEP 2: On-site evaluation

Guidelines

The Charging Station selected in STEP 1 must meet some guidelines:

1. Technical standards and testing laboratory requirements
2. Appropriate rated enclosure (provide protection against environmental hazards)
3. Supply customer's vehicle needs: most vehicles recommend a maximum of a 240V / 32A circuit (40A breaker)
4. Local and national requirements and rules

Charging station location:

1. Parking decks and spaces
2. Parking lots and spaces
3. On-street parking and spaces
4. (Residential garage)
5. (Residential carport/driveway)

On-site evaluation

On-site evaluation for charging stations 1, 2 and 3: select appropriate parking spaces based on (Green eMotion, 2015) (Plug-in Electric vehicle handbook for Public Charging Station hosts, 2012):

- *visibility*: easily visible and recognizable by cars passing
- *accessibility*
- *proximity to power source* → can save costs!
- *high profile*: during the initial phase, desirable that the public notice and recognize charge points in high profile urban areas
- *accessibility*: 24 hour access is highly desirable
- *parking*: if possible car parking spot(s) dedicated to EV parking with some kind of EV parking identification and restrictions to allow EV parking only
- Appropriate length and width of parking spaces

- Avoid infrastructure
- Lighting and shelter
- Connector and enclosure height
- Dust polluting probability: for example proximity to sea/river can cause damage to the charger, meaning higher maintenance costs
- Space around enclosure for safe operation and maintenance
- Physical damage prevention, vandalism
- Tripping hazard mitigation (minimize intersection of cords)
- Aesthetics

→ Based on the on-site evaluation conclude:

i. Parking space
ii. Power source
iii. Need for electrical upgrade

All the decisions have to be checked with national laws and local guidelines, and the permit from local authority has to be acquired. For doing so it is important to contact and inform: jurisdiction's building department, planning department, police, DSO (distribution system operator) (other interested parts in the specific installing cases should be informed as well).

→ Reinforcement estimation approved, with the engineering calculations ("Technical Feasibility" for more info) if necessary

→ Prepare economic business model ("Economic Feasibility" for more info)

→ Verify customer acceptance ("Customer acceptance" for more info).

STEP 3: Installation

→ Permit application filed

→ Price quote submitted to customer and approved

→ Site plan modification completed, with the electrical upgrade if necessary

→ Scheduling work

→ Electrical upgrade (if necessary) + installation process:

a. Excavation
b. Run conduit from power source to station location
c. Rough inspection
d. Lay cables
e. Prepare and mount the charging station following the manufacturer instruction
f. Install protective bollard(s) and/or wheel stop(s) if necessary
g. Install electrical panels that may be necessary
h. Utility work performed (meter)
i. Make electrical connection
j. Reparation in case of damages during the previous steps
k. Replacement of external surfaces

→ Final inspection of the total work and safety of the station

→ Economic model presented in STEP 2 with additional expenses in case of unexpected events or situation

→ Work completed/performance verified

→ Resister the charger infrastructure on public lists (when they exist).

STEP 4: Maintenance

→ Maintenance is a cost!

Typical required maintenance (Green eMotion, 2015):

- Daily inspection of output cable connector, intake and exhaust vents and charge point exterior
- Monthly inspection of ventilation filters
- Bi-annual replacement of ventilation filters
- Bi-annual inspection of high current paths for sign of discolouration
- Replacement of batteries on PCBs
- Planned software upgrades
- Cleaning charger component
- Fix charge components in case of vandalism.

Template elaborated from (Charging Station Installation Handbook for Electrical Contractors and Inspectors, 2013).

Technical Feasibility:

A high penetration of electric vehicles (EVs) in the transportation sector would increase the total electricity consumption (Calearo, Thingvad, Suzuki, & Marinelli, 2019).

To determine if the power grid is able to support the charger infrastructure in analysis 4 main parameters have to be investigated:

- Transformer loading
- Cable loading
- Power losses
- Voltage unbalances.

Economic Feasibility:

Help questions for business model:

1. Who support the charging infrastructure?
2. Is the area/building for the charger infrastructure a new/old place? If it is old, consider the consequences on the price due to a larger need of installation work!
3. How is the customer interaction?
4. Which values and services does the business create?
5. How is the service delivered?
6. What are the benefits and the challenges?
7. What will it cost?
8. Is there revenue? And how is the revenue generated?
9. Is there possibility of scaling?

Charging station:

Costs:

- equipment
- installation
- maintenance
- electricity
- discounts and incentives
- warranty

Benefits:

- user charging and parking fees
- customer attraction and retention
- employee attraction and retention
- corporate branding opportunities
- government funding and incentives
- fleet cost savings
- advertising and customer info opportunities
- contribution to LEED certification
- value of avoided carbon emissions
- public health benefits
- increased energy independence and security

For more info about the prices (Plug-in Electric vehicle handbook for Public Charging Station hosts, 2012).

→ If the charger is not private (houses) a payment system for the customers has to be defined.

Payment options: cash, Radio-Frequency Identification (RFID) cards specific to charging network operators, mobile phone or direct communication between the car and charger, SMS payment, and payment with credit cards.

Revenue:

- price per charge, kWh, minute/hour of charging, and/or minute/hour of parking
- utilization – how much the charge point is used
- other uses of charging station or area – such as marketing on charger and concessions sold.

Example expenses

Example expenses from previous project analysis (Green eMotion, 2015):

AC charge post	Ireland	Germany	Italy	Den mark	Spain	France
1. Method to install street Charge Posts (CPs) including any public private charging units	Install by using sub-contractors	Install by using sub-contractors	Depends: One contractor or sub-contractors	NA	Install by using one specialist contractor	Depends: One contractor or sub-contractors
2. Range of money paid for CP	€2700(1ph)-€6700(3ph)	NA	€1500-€2500	Ca. €6000 (AC)	Ca. €3000/€3500	€2200/€3000 (3 kW)
3. Extra equipment for installation	Average cost €500	NA	Included in 2.			
4. Money for civil/undergroud portion installation	1300/3100€	300-3800€	1000-5500€ (1500-11500€ if separate connection to grid	NA	Average 3000€ for each CP	€1500 → 3 kW €3300 → 22 kW
5. Money for grid portion of installation	Absorbed by Irish utility Network	1700-4000€	450€ (3 kW) 2100€ (22 kW)	NA	Included in 4.	Depend on local grid configuration
6. Money for post connection portion of installation	Absorbed by Irish utility Network	100-500€	Included in 2.	NA	Included in 2.	€200 → 3 kW €800 → 22 kW
7. Money for commissioning portion of installation	Absorbed by Irish utility Network	250-650€	Included in 2.	NA	Included in 2.	NA
8. Money for continuous operation and maintenance of CP infrastructure	Absorbed by Irish utility Network	100-2100€ Depend on: vandalism, failures, theft..	500-750€/year/CP	NA	NA	

DC charge post	Ireland	Germany	Italy	Denmark	Spain	France
1. Method to install street Charge Posts (CPs) including any public private charging units	Combination of Irish utility Networks, a specialist contractor and private contractors	Combination of contractor, sub-contractor etc.	2012 no DC chargers	NA	NA	2012 no DC chargers
2. Range of money paid for CP	10000-26055€	NA		50000€. Grid connection: 6000€	20000-26000€	
3. Extra equipment for installation	300-500€	400-3500€			2000-3000€	
4. Money for civil/undergroud portion installation	4000/16000€	700-4300€		NA	7000-15000€	
5. Money for grid portion of installation	Absorbed by Irish utility Network	3500-7000€		NA	3000-5000€	
6. Money for DCP connection portion of installation	Included in installation and purchase equipment	300-1200€		NA	300-1000€	
7. Money for commissioning portion of installation	1050€	550-1250€		NA	500-3000€	
8. Money for continuous operation and maintenance of CP infrastructure	NA	400-2200€.		NA	3000-6000€/CP	

Customer acceptance:

To satisfy the customer requirements, it is important to verify the choices taken focusing on:

- location
- opportunity of different choices
- safety
- *simplicity* of finding charging stations, use them and pay
- charging time: not always it is important to charge fast, sometimes it is important the time of the day when customers have the possibility to charge (night or day), charging time etc..

Incentivize EV adoption:

- parking incentives
- EVs access (where gasoline cars cannot access)
- Infrastructure: tax rebate on installation EV chargers etc.
- Direct incentives for vehicles
- Information and encouragement.

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