Delivery no.: 2.2.a and 2.2.b
Design specification

Photo: By & Havn / Ole Malling

Radius Elnet
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Public deliverable ☑
Confidential deliverable ☐

Preface

EnergyLab Nordhavn – New Urban Energy Infrastructures is an exciting project, which will continue until the year of 2019. The project will use Copenhagen's Nordhavn as a full-scale smart city energy lab, which main purpose is to do research and to develop and demonstrate future energy solutions of renewable energy.
The goal is to identify the most cost-effective smart energy system, which can help counteract the climate challenges the world are facing.

Budget: The project has a total budget of DKK 143 m (€ 19 m), of this DKK84 m (€ 11 m) funded in two rounds by the Danish Energy Technology Development and Demonstration Programme (EUDP).

Forord

EnergyLab Nordhavn er et spændende projekt der løber til og med 2019. Projektet vil foregå i Københavns Nordhavn, og vil fungere som et fuldskala storbylaboratorium, der skal undersøge, udvikle og demonstrere løsninger for fremtidens energisystem.
Målet er at finde fremtidens mest omkostningseffektive energisystem, der desuden kan bidrage til en løsning på de store klimaudfordringer verden står overfor nu og i fremtiden.

Budget: Projektets totale budget er DKK 143 mio. (EUR 19 mio.), hvoraf DKK 84 mio. (EUR 11 mio.) er blevet finansieret af Energiteknologisk Udviklings- og Demonstrationsprogram, EUDP.

Project Information

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Table of Contents

List of Abbreviations

Executive Summary

The delivery describes where we have installed measurements in the grid, 10 kV as well as 0.4 kV grid. It also describes the design of the 10 kV and 0.4 kV grid.
10 kV measurements are all placed in feeders in Primary Substation “Nyborggade Transformer station” (NGT).
The 0.4 kV measurement is placed in Secondary Substation 40086 “Århusgade Nord”.

All measurements in the grid, measure EnergyLab Nordhavn customers as well as customers outside the project. It is not possible to only measure ELN project customers in the grid, due to the fact, that it is very few customers in the ELN project compared to customers outside the ELN project.

Version Control

Version	Date	Author	Description of Changes
2	19-12-2016	Ole Michael Pedersen	Measurements in 10 kV grid No measurements in 0.4 kV grid
3	03-04-2017	Ole Michael Pedersen	Measurements in 10 kV grid Measurements in 0.4 kV grid
4	16-06-2017	Ole Michael Pedersen	Measurements in 10 kV grid Measurements in 0.4 kV grid

Quality Assurance

Author	Reviewer	Approver
Ole Michael Pedersen	Chresten Træholt	WPL group

Status of deliverable		
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Reviewed	Chresten Træholt	**29-05-2017**
Verified	Benny Stougaard Hansen	26-06-2017
Approved	WPL group	**10-07-2017**

1. Introduction

Radius Elnet has the responsibility of ensuring delivery of electric power to approximately 960.000 homes and businesses in the Copenhagen area, Frederiksberg and Northern Zealand, as illustrated by the dark area in Figure 1.

Figure 1 – Radius Elnet area of supply.

To facilitate a high level of security of supply, Radius Elnet is continuously improving the grid, which entails that monitoring, maintaining, and expanding the grid is an ongoing process.

In urban areas, expanding and establishing electric infrastructure can be extremely expensive, which entails that an accurate dimensioning of the grid is an imperative requirement for a cost-efficient operation.

2. Energy Lab Nordhavn (ELN) customers

ELN customers are located in Århusgade area, Sundkaj area and Levantkaj Vest area. In these areas, Energy Lab Nordhavn customers and partners are in the construction areas 1.07, 1.11, 1.13, 1.15, 1.16, 1.17, 1.30, 4.01, 5.03, 5.10, 5.18 all shown in figure 2. These construction areas furthermore include customers outside the ELN project. Apartments with ELN customers are mixed in the buildings with apartments with customers outside the ELN project.

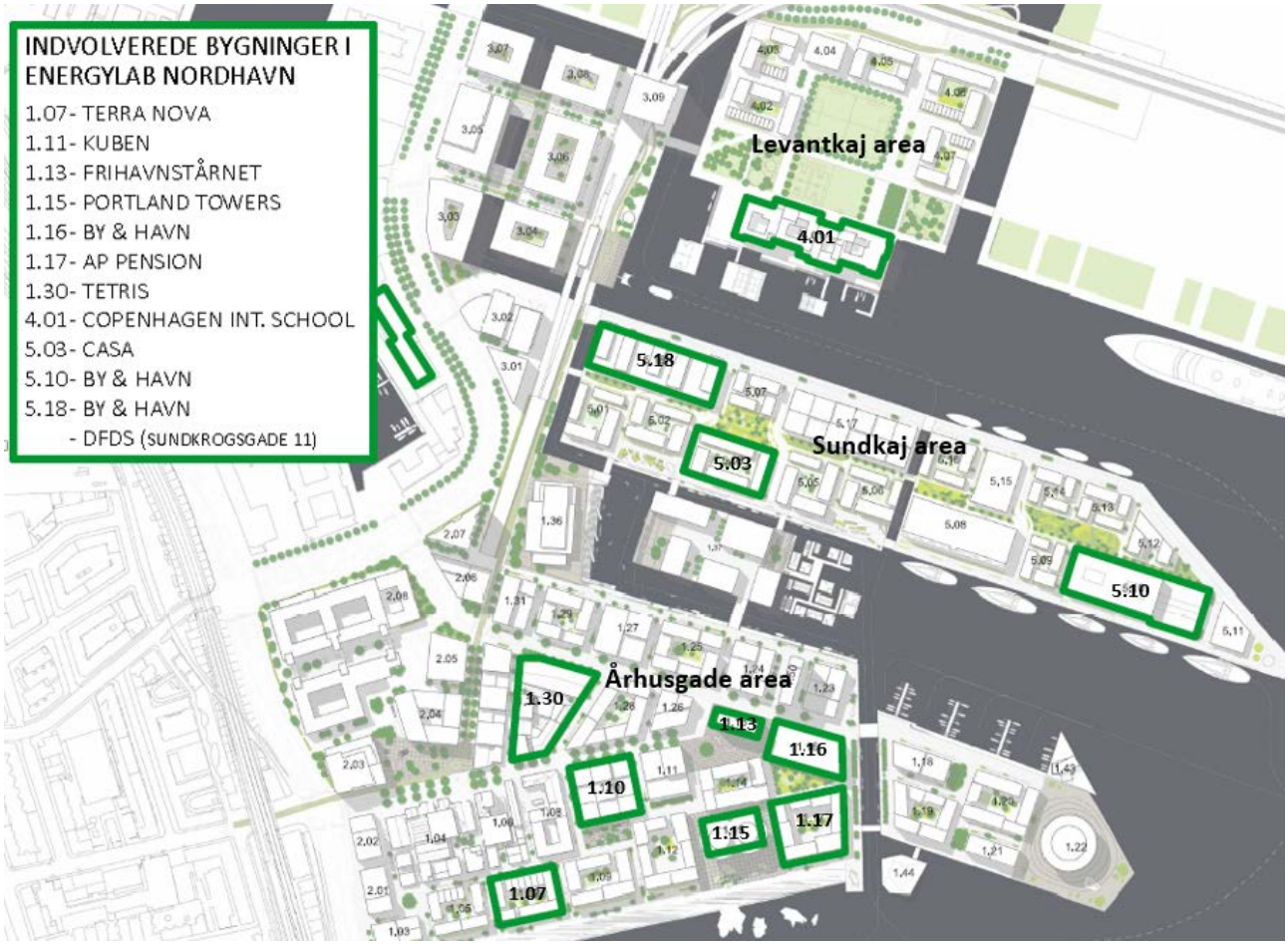

Figure 2

3. 10 kV grid in general

The 10 kV grid feeding Nordhavn is schematic build as shown in figure 3. Each feeder is named starting with the primary substations initials followed by a number, e.g. “NGT 65” for “Nyborggade transformer station”. In chapter four is listed the specific feeders feeding ELN customers in the Nordhavn area.

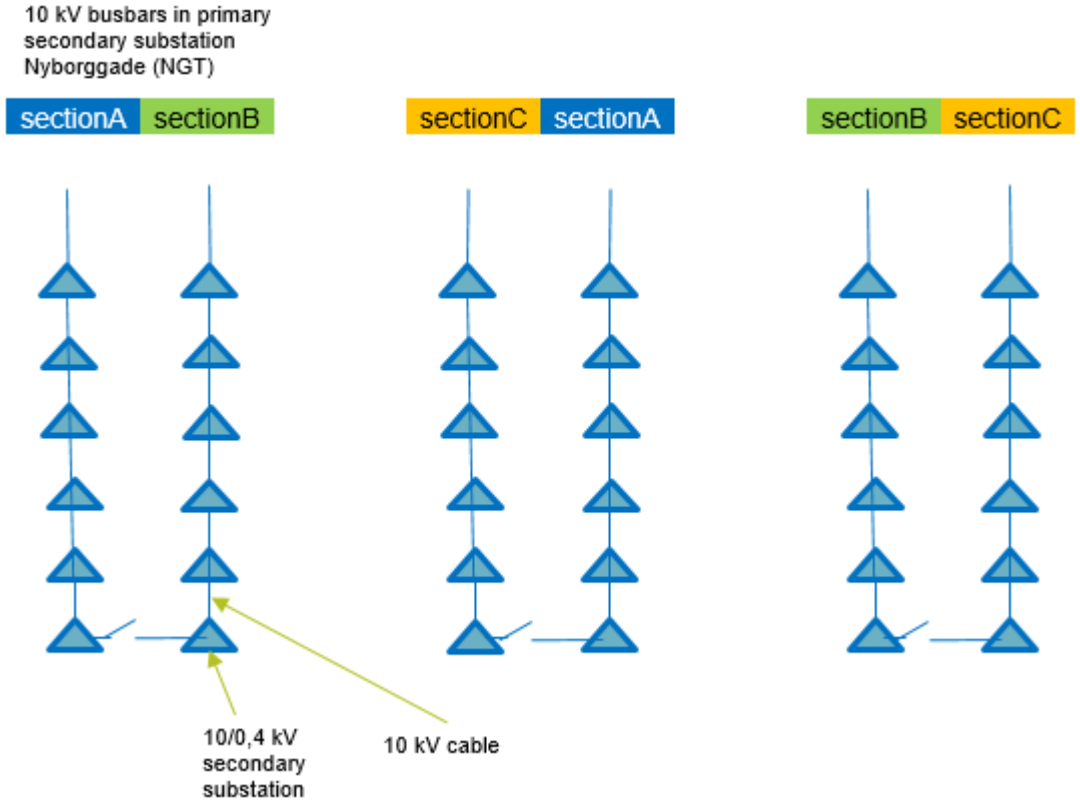

Figure 3

4. 10 kV grid measurement in Nordhavn

In order to get the Battery Energy Storage System (BESS) to do peak shaving, the algorithm needs load information from the 10 kV loop feeding BESS (NGT 08 and NGT 65, figure 4). We therefore establish measurements in these 10 kV feeders. In addition to these two measurements, we plan to measure all 10 kV feeders feeding Nordhavn areas containing ELN customers (areas mentioned in chapter 2). All 10 kV measurements are installed in the Primary Substation Nyborggade (NGT). This gives us measurements in the following feeders:

10 kV feeders in Århusgade area (figure 4):
NGT 16 supplying TETRIS, PORTLAND TOWERS, TERRA NOVA, FRIHAVNSTÅRNET, KUBEN
NGT 08 supplying only customers outside ELN project. Measurement used for peak shaving.
NGT 65 supplying AP PENSION, BESS. Measurement used for peak shaving.
NGT 56 supplying only customers outside ELN project.

Feeder in Sundkaj area (figure 5):
NGT 15 supplying CASA

Feeder in Levantkaj area (figure 6)
NGT 57 supplying COPENHAGEN INTERNATIONAL SCHOOL

All feeders mentioned will have ELN customers as well as not ELN customers. These data are now accessible for the DTU data warehouse. Resolution and communication interface is given in table 2 in chapter 7.

The measurements are only measured as current. For the BESS algorithm, we must calculate the power/energy via the equation: U x I x sqrt3. It is therefore not possible to get the direction of the energy. As we see it, the direction always will be outgoing from the primary substation towards the grid. The local energy production is too low, compared with the load to make the power & energy to flow from the grid towards the primary secondary substation. Furthermore, we only inject energy into the grid, when NGT load is bigger than set point for peak shaving.

The 10 kV grid schematic topology and geographic placement of the 10/0, 4 kV secondary substations in Århusgade area

The top of the figure shows the three loops with its specific 10/0.4 kV secondary substations feeding Århusgade area. The loops are colored
GREEN (NGT 16 – NGT 59)
BLUE (NGT 08 – NGT 65)
YELLOW (NGT 56 – NGT 39)
The loops have each an open circuit breaker (**x**) which divides each loop into 2 feeders, e.g. GREEN (NGT 16 – NGT 59) is in normal operation two independent feeders NGT 16 and NGT 59.

The secondary substations are also showed where they are placed geographical, and have the color responding to the 10-kV loop from which they are fed.

Furthermore, the figure has a little scheme, telling the number of customers that are fed from each feeder. These customers are ELN customers as well as customers outside the ELN project.

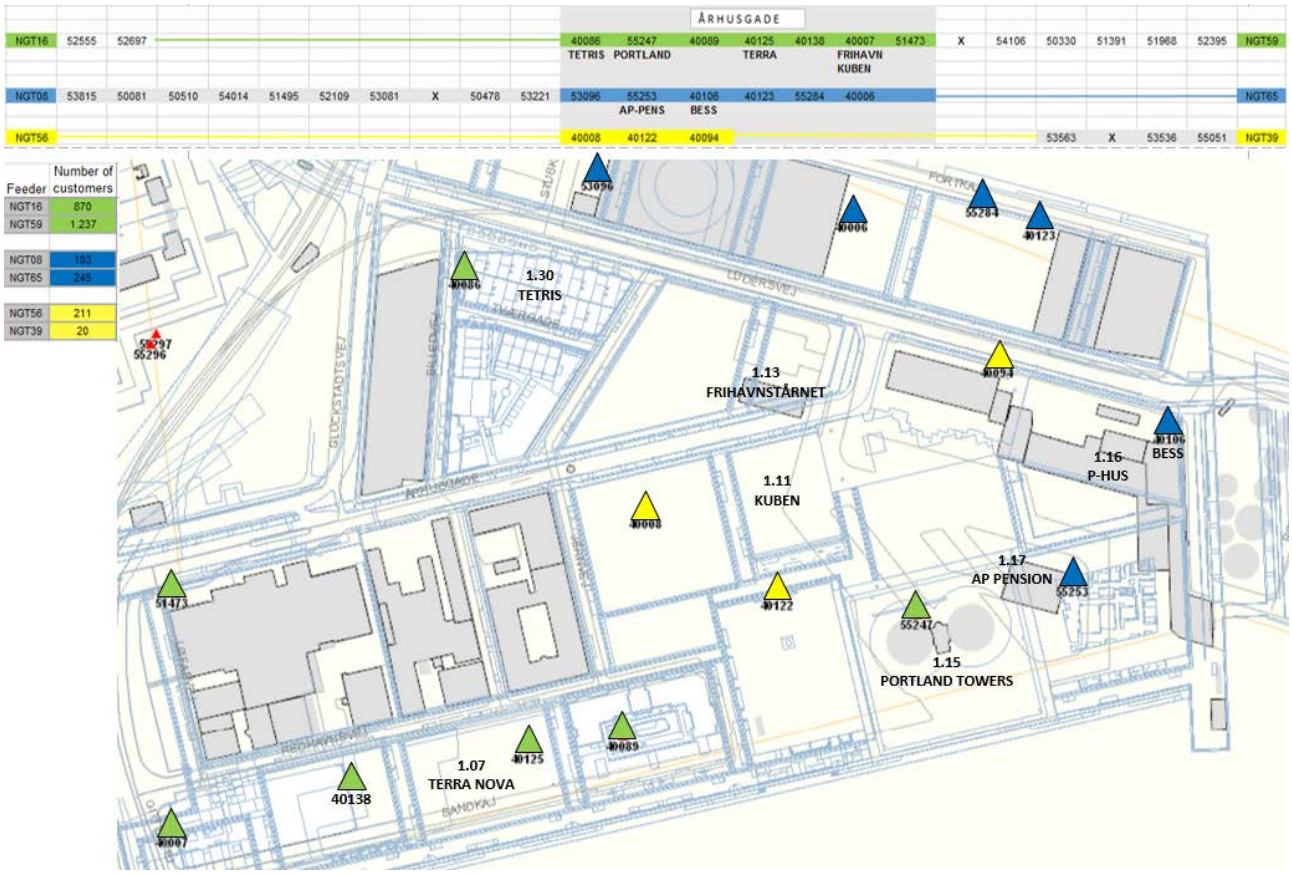
ÅRHUSGADE
NGT16 52555 52697 40086 55247 40089 40125 40138 40007 51473 X 54106 50330 51391 51968 52395 NGT59
TETRIS PORTLAND TERRA FRIHAVN KUBEN
NGT08 53815 50081 50510 54014 51495 52109 53081 X 50478 53221 53096 55253 40106 40123 55284 40006 NGT65
AP-PENS BESS
NGT56 40008 40122 40094 53563 X 53536 55051 NGT39
Feeder
Number of customers
NGT16 870
NGT59 1.237
NGT08 103
NGT65 245
NGT56 211
NGT39 20
1.30 TETRIS
1.13 FRIHAVNSTÅRNET
1.11 KUBEN
1.16 P-HUS
BESS
1.17 AP PENSION
1.15 PORTLAND TOWERS
1.07 TERRA NOVA
40138
LUDERSVEJ
GLOCKSTADTSVEJ
RÅDHUSGADE
REDHAVSVEJ
SANDKAJ

Figure 4

The 10-kV grid schematic topology and geographic placement of the 10/0, 4 kV secondary substations in the Sundkaj area

The top of the figure 5 shows the loop schematically with its specific 10/0.4 kV secondary substations feeding the Sundkaj area. The loop are colored
PURPLE (NGT 15 – NGT 55)
The loop has an open circuit breaker (x) which divides the loop into 2 feeders.

The geographical location of the secondary substations is also shown, and is colored purple corresponding to the 10-kV loop from which it is fed.

Furthermore, figure 5 have a little scheme, telling the number of customers that are fed from each feeder, e.g. 88 from NGT 15 and 138 customers from NGT 55 respectively. These customers are ELN customers as well as customers outside the ELN project.

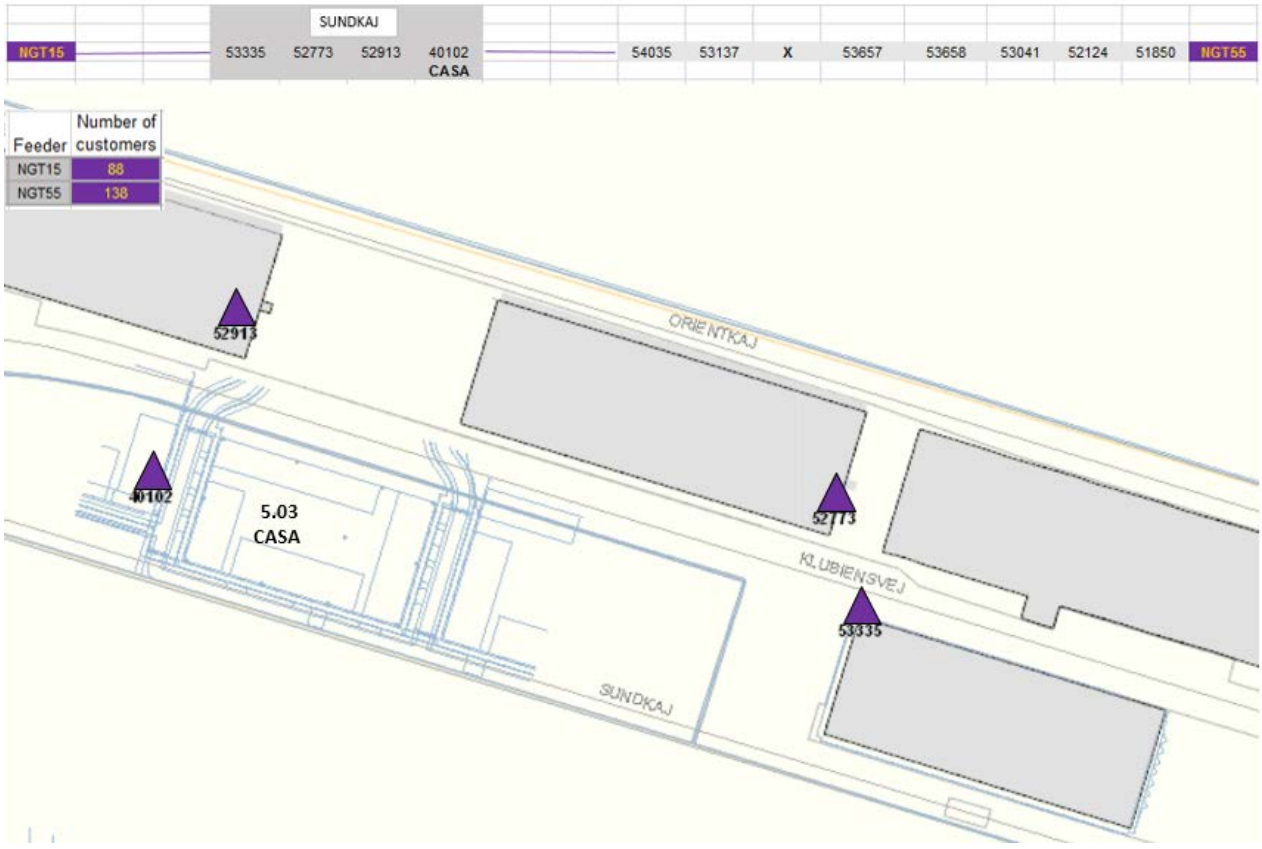

Figure 5

The 10-kV grid schematic topology and geographic placement of the 10/0, 4 kV secondary substations in the Levantkaj area

The top of figure 6 shows the loop with its specific 10/0.4 kV secondary substations feeding Levantkaj area. The loop are colored
ORANGE (NGT 57 – NGT 26)
The loop has an open circuit breaker (x) which divides the loop into 2 independent feeders.

The geographical location of the secondary substations is also shown and has the color corresponding to the 10-kV loop from which it is fed.

Furthermore, figure 6 has a little scheme, telling the number of customers that are fed from each feeder. These customers are ELN customers as well as customers outside the ELN project.

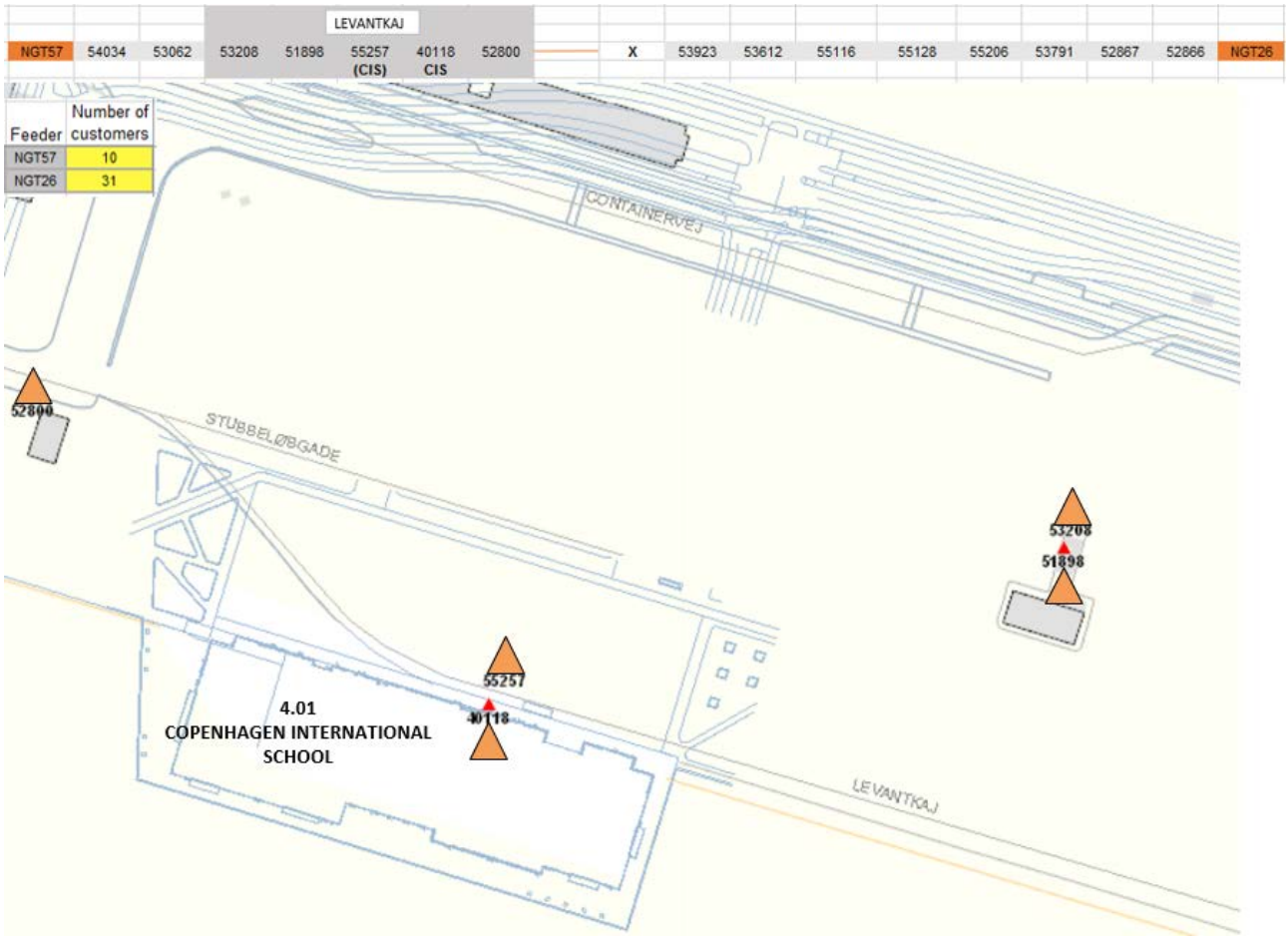

Figure 6

5. 0.4 kV grid in general

The 0.4 kV grid feeding Nordhavn is schematic build as shown in figure 7.
Each cable box is fed from several 0.4 kV cables. Customers are fed via “stikledninger” (cable branch) connected in the small cable boxes, Kabelskab type 2, shown in figure 7 or in the 0.4 kV busbar inside the secondary substation. The big cable boxes, Forsyningsskab type 1, in figure 7 are for making the right topology, and have normally no customers connected. Households in the ELN project are fed from cable boxes which also feeds households outside the ELN project.
Due to the 0.4 kV topology and that customers in the ELN project and outside the ELN project are fed through common cables, it will not be possible to get the load picture of individual ELN customers via measurements in the 0.4 kV grid.

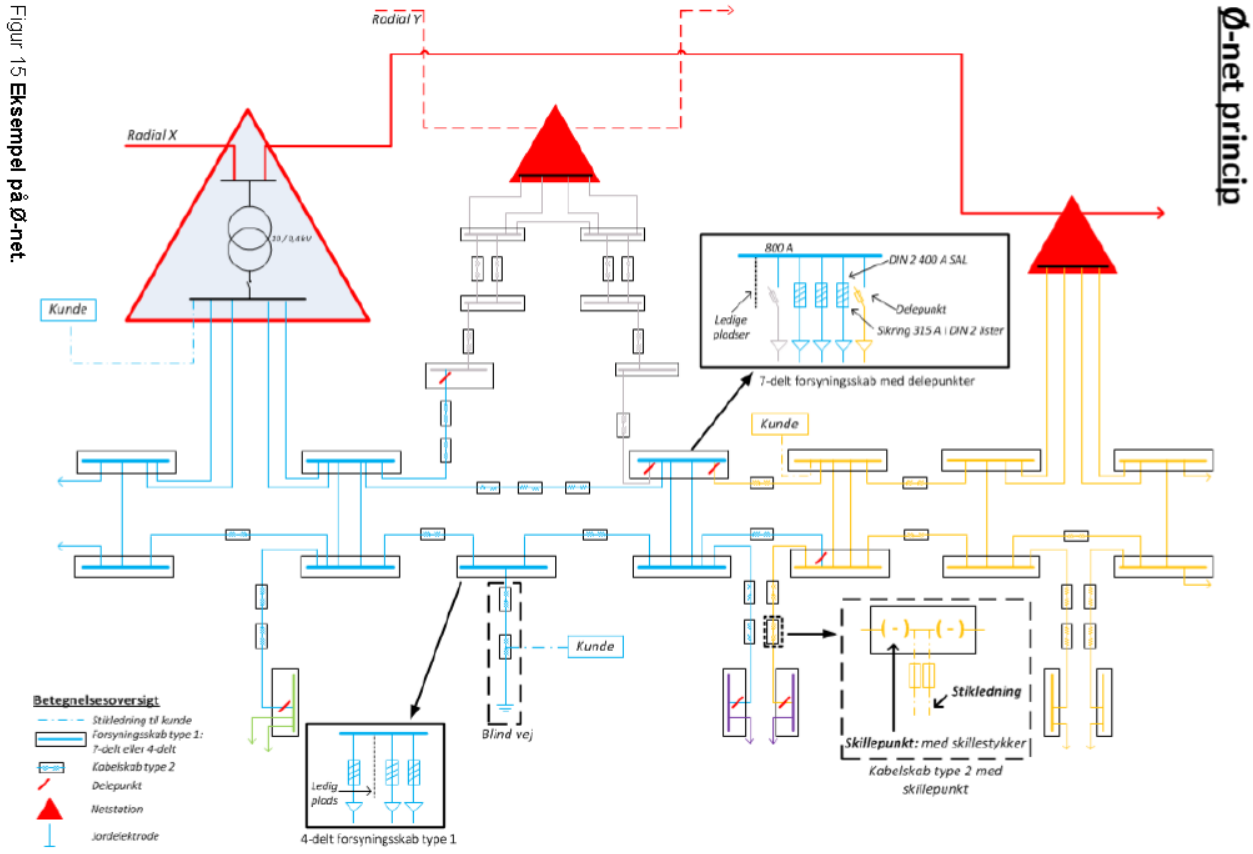

Figure 7

6. 0.4 kV grid measurement in Nordhavn

In addition to our proposed approach in section 5, we have decided to install measurements in secondary substation 40086 Århusgade Nord. These measurements will give us load from customers outside as well as inside the ELN project. This is due to the topology of the 0.4 kV grid, as described in section 5. It is simply not possible to measure only the customers in the ELN project via measurements in the grid.

The secondary substation 40086 Århusgade Nord feeds the customers shown in the table 1. Customers outside the ELN project are grey, customers in the ELN project are yellow, green and orange. The measurements will give us the total load for all customers.

Table 1. List of customers connected to 40086 Århusgade substation.

10KV Radial	Netstation	Udføring, LV-strækning, skab	Skabsnr	Conn. Obj. ID	Device Location ID	Fuse size	Cable dimension	Installation Number	Point of delivery ID	Business Partner	Name 1/Last Name	Address Line 1	Street	House Number
NGT16	40086	2	35759	81775090	#	250	4X185 AL	02/701438456	571313161170162090	602264450	KPC København A/S	Bilbaogade 8X	Bilbaogade	8X
NGT16	40086	4	Not assigned	81866917	81866918	160	2X4X185 AL	02/701573060	571313179100053462	602342538	Grundejerforeningen Frikvarteret	Århusgade 131	Århusgade	131
NGT16	40086	4	Not assigned	81866917	81866922	160	2X4X185 AL	02/701573066	571313179100054018	602342539	Ejerforeningen Det Grønne Hjørne	Århusgade 131	Århusgade	131
NGT16	40086	12653-3--35008-3	8450	81145594	81174889	63	4X16 CU	02/720507328	571313161105073286	602245974	Udviklingsselskabet By & Havn I/S	Glückstadtsvej 4	Glückstadtsvej	4
NGT16	40086	12653-3--35008-3	Not assigned	81064554	81513185	80	4X95 CU	02/720497936	571313161104978567	602228203	Udviklingsselskabet By & Havn I/S	Billedvej 8	Billedvej	8
NGT16	40086	12653-3--35008-3	Not assigned	81064554	81517122	80	4X95 CU	02/720497937	571313161104979374	602343952	UDVIKLINGSSELSKABET BY & HAVN I/S	Billedvej 8	Billedvej	8
NGT16	40086	12653-3--35008-3	Not assigned	81064554	81520356	80	4X95 CU	02/720497692	571313161104976922	602212532	Udviklingsselskabet By & Havn I/S	Billedvej 8	Billedvej	8
NGT16	40086	12653-3--35008-3	Not assigned	81064554	81520362	80	4X95 CU	02/720497693	571313161104976939	602378715	Udviklingsselskabet By & Havn I/S	Billedvej 8	Billedvej	8
NGT16	40086	12653-3--35008-3	Not assigned	81064554	81520360	80	4X95 CU	02/720497695	571313161104976953	570252446	HOW Administration A/S	Billedvej 8	Billedvej	8
NGT16	40086	12653-3--35008-3	Not assigned	81140464	81196932	Not assigned	Not assigned	02/720507880	571313161105078809	602262806	Udviklingsselskabet By & Havn I/S	Southamptongade 2	Southamptongade	2
NGT16	40086	12653-3--35008-3	Not assigned	81145621	81259645	Not assigned	Not assigned	02/720545967	571313161105459677	601077512	Udviklingsselskabet By & Havn I/S	Southamptongade 2	Southamptongade	2
NGT16	40086	12653-3--35008-3	Not assigned	81145621	81277399	Not assigned	Not assigned	02/720545893	571313161105458939	602374280	Udviklingsselskabet By & Havn I/S	Southamptongade 2	Southamptongade	2
NGT16	40086	12653-3--35008-3	Not assigned	81145621	81499411	Not assigned	Not assigned	02/720473350	571313161104733501	602352693	Forward Capital A/S	Southamptongade 2	Southamptongade	2
NGT16	40086	12653-3--35008-3	Not assigned	81149073	81514830	Not assigned	Not assigned	02/720473343	571313161104733433	602210695	Bredr. Jørgensen A/S	Århusgade 127	Århusgade	127
NGT16	40086	12653-3--35008-3	Not assigned	81149881	81191638	Not assigned	Not assigned	02/720514923	571213161105140230	570252477	Plasser Scand. (Plasser Scand. AG)	Dansk FiLAl Plasser Scand. Ltd Sch	Århusgade	130
NGT16	40086	12653-3--35008-3	Not assigned	81149881	81513158	Not assigned	Not assigned	02/720497935	571313161104979350	601097821	Sea Ranch ApS	Henrik Aas	Århusgade	130
NGT16	40086	12653-3--35008-3	Not assigned	81157568	81514848	Not assigned	Not assigned	02/720473344	571313161104733440	602210890	Udviklingsselskabet By & Havn I/S	Rostockgade 7	Rostockgade	7
NGT16	40086	34542-1--34565-7	34639	81851185	81851186	25	4X6 CU	02/701555982	571313161170301864	602175033	Annemette Dal Svarer	Morten Uglebjerg	Kielgade	7
NGT16	40086	34542-1--34565-7	34639	81851187	81851188	25	4X6 CU	02/701555984	571313161170301871	602175035	Peter Thiesl Jessen	Tonje Bergholm Vestby	Kielgade	9
NGT16	40086	34542-1--34565-7	34639	81851189	81851190	25	4X6 CU	02/701555986	571313161170301796	602355301	Phung Vo	Kielgade 11	Kielgade	11
NGT16	40086	34542-1--34565-7	34639	81851291	81851292	25	4X6 CU	02/701556087	571313161170302052	602164603	Signe Jensen	Jonas Groes	Helsingkgade	6F
NGT16	40086	34542-1--34565-7	34639	81851293	81851294	25	4X6 CU	02/701556089	571313161170302113	602164605	Daniel Cortes	Helsingkgade 6G	Helsingkgade	6G
NGT16	40086	34542-1--34565-7	34639	81851330	81851331	25	4X10 CU	02/701556129	571313161170302120	602291081	Ulrik Graff	Justine Wicikowski	Kielgade	2
NGT16	40086	34542-1--34565-7	34639	81851332	81851333	25	4X6 CU	02/701556131	571313161170302137	602291059	Rune Højby Kock	Siri Højby Kock	Kielgade	4
NGT16	40086	34542-1--34565-7	34639	81851337	81851338	25	4X6 CU	02/701556136	571313161170302069	602291057	Knid Jellesen	Hanne Krigslund	Kielgade	6
NGT16	40086	34542-1--34565-7	34639	81851341	81851342	25	4X6 CU	02/701556140	571313161170302076	602291056	Per Stengade	Helle Honig	Kielgade	8
NGT16	40086	34542-1--34565-7	34639	81851350	81851351	25	4X6 CU	02/701556149	571313161170302151	602291037	Klaus Frandsen	Susanne Leth	Kielgade	10
NGT16	40086	34542-7--35008-1	34638	81851278	81851279	25	4X6 CU	02/701556073	571313161170301956	602164440	Charlotte Damsbo Lose	Heino Jacobsen	Helsingkgade	6A
NGT16	40086	34542-7--35008-1	34638	81851280	81851281	25	4X6 CU	02/701556075	571313161170301963	602164502	Christina Pohani	Peter Pohani	Helsingkgade	6B
NGT16	40086	34542-7--35008-1	34638	81851283	81851284	25	4X6 CU	02/701556079	571313161170301970	602164594	Helle Jensen	Jesper Termansen	Helsingkgade	6C
NGT16	40086	34542-7--35008-1	34638	81851285	81851286	25	4X6 CU	02/701556081	571313161170302108	602184597	Arndi Dines Dalsgaard Hansen	Karen Agnethe Hari	Helsingkgade	6D
NGT16	40086	34542-7--35008-1	34638	81851289	81851290	25	4X6 CU	02/701556085	571313161170301987	602164599	Anders Ødegaard Christiansen	Jane Greve	Helsingkgade	6E
NGT16	40086	34542-7--35008-1	34638	81867882	81867883	25	4X6 CU	02/701573952	571313179100066677	602300111	TDC A/S	Helsingkgade 6	Helsingkgade	6
NGT16	40086	34565-1--35008-5	34636	81829520	#	63	4X16 CU	02/701478419	571212161170225337	602243331	Rasmus Friis A/S	Århusgade 133, Y MSO	Århusgade	133
NGT16	40086	34565-1--35008-5	34637	81851179	81851180	25	4X6 CU	02/701555976	571313161170301833	602175008	Marcus Jacobsson	Camilla Jacobsson	Kielgade	1
NGT16	40086	34565-1--35008-5	34637	81851181	81851182	25	4X6 CU	02/701555978	571313161170301840	602175006	Michael Aagaard	Mie Duemose Jensen	Kielgade	3
NGT16	40086	34565-1--35008-5	34637	81851183	81851184	25	4X6 CU	02/701555980	571313161170301857	602175010	Morten Christian Erichsen	Dorthe Bjerremand Erichsen	Kielgade	5
NGT16	40086	34565-1--35008-5	34637	81851398	81851399	25	4X6 CU	02/701556185	571313161170302090	#	#	#	#	#

We believe, that in addition to the measurements we have from each customer, via RPM (Remote Power Meters) measurements it will be possible to generate useful information regarding the influence from the ELN initiatives.

7. Field measurements design

As described, ELN customers are mixed with customers outside the ELN project, on 10 kV level as well as on 0.4 kV level.
Due to this, it is not possible to establish measurements in the grid, which measures only ELN customers.
However we have

- established 10 kV measurements in all 10 kV feeders with ELN customers as described in section 4
- established 0.4 kV measurement in one secondary substation, feeding some ELN customers, as described in section 6

In addition to the mentioned measurements, we suggest looking into RPM´s in the households. To obtain measurements for each building, it is possible to summarize measurements from individual customers. The data can be obtained through Radius' RPM meters with hourly resolution from all households in the Nordhavn area, or through KNX based bi-meter with 1 sec resolution for the buildings and apartments, which participate in the ELN project and have installed KNX system. Balslev have registered customers that have installed the KNX system.

Radius Elnet have by now installed RPM in all households in Nordhavn area. Households, who act only as consumers, will be Kamstrup meters. Households that also generate power, e.g. with PV's installed, are not Kamstrup meters. This will complicate our set up, but it will be possible to do one of following:

1. The data from Radius meters will end in a Meter Data Management MDM (please write in full the first time)-system as active power (kWh) with 1-hour time resolution. If we get the addresses from costumers we want to analyze this, values can be provided in a spreadsheet with a few days' delay, to DTU. The meters that are not Kamstrup meters (installations with power generation), can also be send as values in an xlsx spreadsheet with a few days' delay to DTU.

2. In Kamstrup meters, a dongle could be placed in a separate port in the meter. The meter can be programmed to store selected values with an optional time resolution (how fine, seconds or better?). Communication system to DTU Data warehouse must be installed at customer's site. To this, we need customers' acceptance. When this setup is in operation, it is possible to get close to real time measurements. The meters which are not Kamstrup (installations with power generation), will be send as values in an xlsx spreadsheet with a few days' delay to DTU.

Table 2. Measurements in the 10 kV and 0.4 kV grid as well as at customer's site that can register/measure load in the grid

Technology	Data available	Customer type	Responsible	Resolution	Data warehouse feed	Comment
RPM via MDM database	kWh	Household	Radius	1 hour	Auto in packages Manual via xlsx	
RPM via MDM database	kWh	Commercial	Radius	1 hour	Auto in packages Manual via xlsx	
RPM online via Panda	kWh	PV	Radius	Online	Manual via xlsx	
KNX meters	kWh	ELN participants	ABB	Real time	Auto	
10 kV RTU from ABB	A	all	Radius	Real time	Auto	Accessible via BESS
0.4 kV Smart Grid Unit from Thiim	U, I, cos phi, active and reactive power, all by each phase	all	Radius	Real time	Auto	Accessible via secondary substation 40086 Århusgade Nord

Abbreviations

RPM = Remote Power Meter
MDM = Meter Data Management
HES = Head End System
Panda = Combination of MDM and HES
RTU = Remote Terminal Unit