TOWARDS SMART ZERO CO_2 CITIES ACROSS EUROPE

VITORIA-GASTEIZ ✣ TARTU ✣ SONDERBORG

Deliverable D.5.5: Solar Cell Storage in Operation

WP5

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Abbreviations and Acronyms

Abbreviation/Acronym	Description
SmartEnCity	Towards Smart Zero CO2 Cities across Europe
B42	Housing Association B42
SAB	Sonderborg Housing Association
SOBO	Housing Association SOBO
ZERO	Project Zero A/S

Table 1: Abbreviations and Acronyms

0 Publishable Summary

Two social housing associations in Sonderborg, DK are involved in the solar cell storage task:

- Sonderborg Housing Association (SAB), Partner 16
- Housing Association SOBO, Partner 17

SAB has 9 of their housing departments with 1,518 apartments involved in the project.
SOBO has 2 departments with 121 apartments involved.
The 11 departments have in total 1,639 apartments with 2,500 residents.
A total of 86 buildings have been retrofitted with solar PV and battery solutions.

The purpose of the deliverable is to inform and inspire other housing associations and other house owners in Europe how to reduce the electricity consumption in their buildings.
The target group is primarily administrators and boards of housing associations plus owners of apartment buildings.

A battery storage solution is an interesting solution for apartment buildings, because solar electricity produced during the day can be stored until the late afternoon or evening, when the electricity consumption is higher than during the day, and thereby also contribute to reducing the peak load demand on the public grid.

The solar PV and battery systems are designed, that a minimum of 80 % of the produced electricity can be used directly via the batteries to the apartments. A maximum of 20 % will be submitted and sold to the public grid.

The deliverable describes the following actions to implement and complete the solar PV and storage systems:

- Decision making process to approve the solar PV and battery systems (01/03/2020 – 30/09/2020)
- Design phase including design criteria (01/01/2020 – 30/06/2020)
- Tender and contract processes (01/02/2020 – 30/09/2020)
- Approval from public authorities (01/09/2020)
- Implementation phase including description and photos of the systems (01/05/2020 – 15/07/2021)
- Approval of construction work and handover to housing associations (31/07/2021)
- Start of monitoring period (15/07/2021)

The total investment in the 11 systems corresponds to 4,271,000 Euro.
The saved purchaced electricity of 1,433 MWh corresponds to 403,000 Euro.
The simple pay-back period will then be 10 years.
However, the combination of solar PV and storage of electricity in batteries is still a new developed technology, and the lifetime of the batteries is still unknown.

1 Introduction

Two social housing associations in Sonderborg, DK are involved in the solar cell storage task:

- Sonderborg Housing Association (SAB), Partner 16
- Housing Association SOBO, Partner 17

SAB has 9 of their housing departments with 1,518 apartments involved in the project.
SOBO has 2 departments with 121 apartments involved.
The 11 departments have in total 1,639 apartments with 2,500 residents involved.

Objectives of the action
The objective of the measures is to implement and demonstrate a new combination of solar PV panels and battery systems to improve the utilization of solar produced electricity.
A battery storage solution is an interesting solution for apartment buildings, because solar electricity produced during the day can be stored until the late afternoon and evening, where the electricity consumption is higher.
The 11 departments with solar PV and batteries will assist Sonderborg with the aim to be a CO2 neutral City in 2029.
Furthermore, the objective is to install systems increasing the intelligent operation of the buildings to assist Sonderborg to be a Smart Energy City. Here is focus on intelligent control of the solar panel and batteries contribution correspondent to the electricity demand.

1.1 Purpose and target group

The deliverable includes a description of the completed solar PV and battery systems in the involved buildings of the housing associations.
Furthermore, there is a description of the decision-making process for the energy measures, a description of the design phase and the tendering phase and a description of the implementation phase.
The purpose of the deliverable is to inform and inspire other housing associations and other house owners in Europe how to reduce the electricity consumption in their buildings and how to solve challenges in connection with the financing process and the decision process prior to the implementation.
The target group is primarily administrators of housing associations and owners of apartment buildings.

1.2 Contributions of partners

The following Table 2 depicts the main contributions from participant partners in the development of this deliverable.

Participant short name	Contributions
ZERO	Author of this deliverable and coordinator of the project.
SAB	Technical and process input to solar PV and battery systems.
SOBO	Technical and process input to solar PV and battery systems.

Table 2: Contribution of partners

1.3 Relation to other activities in the project

The following Table 3 depicts the main relationship of this deliverable to other activities (or deliverables) developed within the SmartEnCity project, and that should be considered along with this document for further understanding of its contents.

Deliverable Number	Contributions
D.5.2	This deliverable provides the overall description of the decision-making process and the tender process.
D.5.3	This deliverable provides the overall description of the involved housing associations and a description of the energy retrofitting measures implemented prior to the solar PV and battery project. D.5.3 also describes the third housing association in Lighthouse Sonderborg: B42.

Table 3: Relation to other activities in the project

2 Objectives and expected Impact

Objectives

The demonstration area in Sonderborg contains different types of residential buildings: A) The inner-city part of Sonderborg with demonstration of brick buildings from 1950-60. B) An ”outer residential building part” outside of the central part dominated by social housing building blocks typical with 2-4 storeys built as concrete elements. For Sonderborg’s strategy as a sustainable community it is most important to maintain/develop these residential areas into attractive housing areas.
The layout of the demonstration area has been defined by having demonstrating buildings from 1950-1980`s, including older buildings from central and more ”outer ring” parts of Sonderborg.

A total of 86 buildings have been retrofitted with solar PV and battery solutions.
Demonstration buildings represent typical and therefore replicable social housing building types and energy measures.
In Sonderborg 30 % of the inhabitants are living in social housing association buildings.

Expected impact

The demonstration buildings consist of the listed 11 social housing departments.
In total 86 buildings with 1,639 apartments and 127.600 m² of built area.

Department	Street	No. Buildings	No. Apartments	Built area m²
SAB - 13	Borgmesterløkken	5	93	7.500
SAB – 15	Klosterløkken	4	105	8.500
SAB - 18	Ryttervænget	9	114	9.100
SAB – 20	Vølundsgade	8	94	7.600
SAB – 21	Rådmandsløkken	6	72	5.800
SAB – 22	Kløvermarken	19	432	32.000
SAB – 24	Søstjernevej	12	324	25.100
SAB – 27	Primulavej	4	52	3.600
SAB – 30	Stenbjergparken	10	232	18.500
SOBO – 12	Grundtvigs Alle	6	72	6.000
SOBO – 21	Udsigten	3	49	3.900
		86	1.639	127.600

Figure 1: Basic data for the involved 11 housing departments

Department	Street	Expected electricity purchace saving kWh/year	kWh/year m2
SAB - 13	Borgmesterløkken	105.000	14,0
SAB – 15	Klosterløkken	125.000	14,7
SAB - 18	Ryttervænget	120.000	13,2
SAB – 20	Vølundsgade	105.000	13,8
SAB – 21	Rådmandsløkken	85.000	14,7
SAB – 22	Kløvermarken*	65.000	-
SAB – 24	Søstjernevej	330.000	13,0
SAB – 27	Primulavej	55.000	15,2
SAB – 30	Stenbjergparken	250.000	13,5
SOBO – 12	Grundtvigs Alle	110.000	18,3
SOBO – 21	Udsigten	60.000	15,4

Figure 2: Expected impact from the solar PV and battery systems

* SAB 22 has an existing solar PV system, to which battery plants have been added. Electricity purchase saving of 65.000 kWh is extra saving due to the batteries.

The solar electricity is expected to cover 45 – 50 % of the total electricity consumption in the housing departments.

3 Overall Approach

To achieve the Deliverable describing the solar PV storage projects in Sonderborg, DK the following steps have been completed:

- Decision process for the solar PV and battery projects.
- Technical design of the systems.
- Tendering process.
- Construction contracts.
- Approval from public authorities.
- Implementation and supervision phase.
- Approval of implementation work and handover.
- Monitoring period.

Partners involved in these phases have been:

ZERO – Partner 15 as overall coordinator.
SAB – Partner 16 as builder and decisionmaker.
SOBO – Partner 17 as builder and decisionmaker.

4 Execution of the Solar PV and Battery projects

4.1 Decision making process

Organisation of social housing associations

The two involved social housing associations are individual legal associations, each with their own board of directors, an executive committee and their own Chief Executive Officer and administration.

The board of directors is elected bottom up with the following process:

- Each housing department in a housing association elects their own department board at a general meeting for all tenants in the department. The department board typically has a chairman and 4-6 members.
- Members from all housing department boards form a general Forum of Representatives for the whole housing association. The general Forum of Representatives often has more than 100 members.
- The general forum elects an Executive Committee for the housing association with 6-10 members.
- The Executive Committee hires a professional Chief Executive Officer for the housing association.
- The CEO hires the staff members of the administration.

Other important stakeholders
In energy construction projects the following stakeholders are typically involved:

- Housing Association and its organisation as the building owner.
- External energy design engineers.
- External contractors (solar companies, electricians, carpenters etc.)
- Finance institutions.
- Building authorities - Sonderborg Municipality.
- Regional electricity distribution company.
- Governmental authorities – Danish Energy Agency

The external companies are hired by the housing associations typically after a tendering process.

Decision making process

- The selected external engineering design company prepares a detailed technical proposal for implementation of solar PV and battery systems for each of the individual departments.
- The technical proposal includes a detailed description of the solar PV- battery system, the expected investments, the expected energy saving in kWh and in currency, finance scheme, influence on the rents of the apartments, the payback period and other positive results of the project like reduction of CO2, contribution to the climate change process etc.
- The proposal is presented and discussed first with the administration, then with the local department board and finally with all the tenants in the department, who need to

approve the proposal and the financial consequences at a general tenant meeting of the department.
- The tenants vote on the proposal for solar PV and batteries, yes or no, and there has to be a simple majority by the tenants present at the meeting to get the proposal approved.
- If the proposal is approved, the administration asks the external engineering design company to prepare tender documents and execute a tender process.

4.1.1 Actual decision process in the two housing associations

The housing associations SAB and SOBO organized the annual tenant meetings, where the proposals for solar PV and batteries were presented, discussed and approved.
Tenant meetings for the involved departments took place on the following days:

- SAB Department 13: Borgmesterløkken on September 14, 2020
- SAB Department 15: Klosterløkken on September 2, 2020
- SAB Department 18: Ryttervænget on September 14, 2020
- SAB Department 20: Vølundsgade on September 10, 2020
- SAB Department 21: Rådmandsløkken on December 3, 2020
- SAB Department 22: Kløvermarken on September 9, 2020
- SAB Department 24: Søstjernevej on September 1, 2020
- SAB Department 27: Primulavej on September 8, 2020
- SAB Department 30: Stenbjergparken on September 16, 2020

- SOBO Department 12: Grundtvigs Alle on September 5, 2019
- SOBO Department 21: Udsigten on September 10, 2020

The proposals were presented, discussed and approved on all the above tenant meetings.

Only one: SAB Department 50: Fiskervænget did not approve the proposal.
The tenant meeting on September 1, 2020 discussed the proposal, and they decided to install solar PV and batteries within 1-2 years, but unfortunately not in the near future.
Therefore, it was not possible to include this department in the SmartEnCity project.

4.2 Technical design criteria

4.2.1 Innovation

Roof integrated solar panels are not new, however the combination with battery storage in the basement of buildings is new, especially because the individual electricity consumption meters in each department are being changes from individual amin meters to internal meters.
Then the solar panels send the electricity to the batteries and from there to the main meter for the whole building. This allows a larger part of the produced solar electricity to be consumed on site. It is not longer necessary to sell all the excess solar electricity to the public grid for a low price.
Battery storage solutions combined with solar PV panels are still under technological development.

New developed type of Lithium batteries are used for demonstration together with solar PV panels. Materials used for manufacturing lithium batteries are in the category “products with low sustainability””. Therefore it was investigated to use so called “flow batteries” based on more sustainable materials instead of lithium batteries. However flow batteries are still in a

development phase, and the investment would be more than double compared to lithium batteries.)

4.2.2 Background for overall design criteria

In solar PV systems without battery storage surplus produced solar electricity is sold to the public grid for at low price of approximately 0.05 Euro per kWh.
Therefor it is important to use the solar electricity directly in the apartments in the same period, as the solar electricity is produced and submit the lowest possible amount to the public grid.
The solar PV and battery systems are designed, so that a minimum of 80 % of the produced electricity can be used directly in the apartments, and a maximum of 20 % will be submitted to the public grid.

If solar electricity can be stored in batteries and used at a later stage, tenants will be able to save 0.30 Euro per kWh, which is the normal price for electricity in Denmark.

A battery storage solution is an interesting solution for apartment buildings, because solar electricity produced during the day can be stored until the late afternoon or evening, when the electricity consumption is higher than during the day, and thereby also contribute to reducing the peak load demand on the public grid.

4.2.3 Specific design criteria

Detailed analyses and calculations during the project have documented, that with batteries included it is economic feasible to install a solar PV area, that is 50 % bigger than a solar PV area without batteries connected.
In comparison to a grid connection which as an example is most feasible with 100 m2 of solar panels, a battery storage solution would be most reasonable with 150 m2 of solar panels connected with a local battery.
With batteries you save a lot more external electricity and a lot more CO2.
Economic calculations also document, that it is most feasible to design a solar PV and battery system, which cover appr. 50 % of the total electricity consumption in the apartments.

4.2.4 Key figures for combination of solar PV and batteries

Detailed analyses and calculations during the project resulted in the following key figures designing feasible combinations of solar PV and battery systems in social housing associations under climatic conditions in Denmark:

- Solar PV power without batteries: 1,000 Watt per apartment.
- Area of PV panels without batteries: 1,000 W / 180 W per m2 = 5-6 m2 per apartment.
- Solar PV power if connected to batteries: 1,500 Watt per apartment.
- Area of PV panels if connected to batteries: 1,500 W / 180 W per m2 = 8-9 m2 per apartment.
- Battery capacity: 1 kWh capacity per 1,700 Watt solar PV corresponding to 1 kWh battery capacity per 9-10 m2 solar PV panels.

4.2.5 Design figures for the 11 Solar PV and Battery Systems

Department	Apartments	Solar PV area	Solar PV	Battery capacity	Solar contribution
	No	m2	kW	kWh	kWh/year
SAB - 13	93	600	110	60	105.000
SAB – 15	105	750	140	80	125.000
SAB - 18	114	730	135	75	120.000
SAB – 20	94	600	110	60	105.000
SAB – 21	72	500	110	50	85.000
SAB – 22*	432			290	65.000
SAB – 24	324	1.870	345	200	330.000
SAB – 27	52	350	65	30	55.000
SAB – 30	232	1.650	295	80	250.000
SOBO – 12	72	670	120	70	110.000
SOBO – 21	49	350	70	55	60.000
	1.639	8.070	1.500	1.050	1.410.000

Figure 3: Design figures for the 11 Solar PV and Battery Systems

* SAB 22 has an existing solar PV system, to which battery plants have been added.
Electricity saving of 65.000 kWh is extra saving due to the batteries.

4.3 Tendering Process.

The rules for tendering depend on the size of the expected investment.
If the investment in the actual tender is expected to be below 5,5 mio. Euro, which it was for SAB and SOBO, then the tender can be executed as a so called “Limited tender process”, where you only need to ask 3 contractors to bid.

4.3.1 Tender process for SOBO Housing Association.

SOBO has executed two limited tender processes, one for Department 12 and one for Department 21.

Tender process for SOBO Department 12.
The management of SOBO Housing Association decided to invite 3 companies to bid for installation of solar PV and battery systems as part of retrofitting the roofs of the buildings.
The three construction companies were:

- Søgård Byg A/S, 6200 Aabenraa
- Hjortgaard A/S, 6400 Sønderborg
- Håndværkerne A/S, Tandslet,6470 Sydals

Tender documents
The engineering design company prepared the tender documents consisting of:

- Tender letter dated 10.02.2020
- Technical description.
- Drawing documents.
- Description of the actual buildings.
- Pricelist for the bids.

The tender was a Main Construction Contract including solar panels, batteries, installation of solar panels and batteries, all electrical installations and the carpenter work preparing the roofs for solar panels.

Evaluation process
The tender letter specified two evaluation criteria for the bids:

- The lowest price for the solar PV and battery installation
  This part of the evaluation counts 70%.

- The technical quality and the solar electricity production is evaluated from 0-10 points, and this part of the evaluation counts 30%

Results of the tender process for SOBO Department 12.
The tender documents were submitted to the invited contractors on February 10, 2020 and the bid should be delivered on March 3, 2020.

The result of the tender process was:
- Søgård Byg: Evaluation point: 100
- Hjortgaard: Evaluation point: 91
- Håndværkerne: Evaluation point: 71

Construction contract
Based on the result of the tender process, the company Søgård Byg A/S was awarded the construction contract, which was signed on March 25, 2020.

Tender process for SOBO Department 21.
The management of SOBO Housing Association decided to invite 3 companies to bid for installation of solar PV and battery systems as part of retrofitting the roofs of the buildings.
The three construction companies were:
- Søgård Byg A/S, 6200 Aabenraa
- Sustain Renewables A/S, 6200 Sønderborg
- Solarpark.dk, 6240 Løgumkloster

Tender documents
The engineering design company prepared the tender documents consisting of:

- Tender letter dated 29.10.2020
- Technical description.
- Drawing documents.
- Description of the actual buildings.
- Pricelist for the bids.

The tender was a Main Construction Contract including solar panels, batteries, installation of solar panels and batteries, all electrical installations and the carpenter work preparing the roofs for solar panels.

Evaluation process
The tender letter specified two evaluation criteria for the bids:

- The lowest price for the solar PV and battery installation
  This part of the evaluation counts 70%.

- The technical quality and the solar electricity production is evaluated from 0-10 points, and this part of the evaluation counts 30%

Results of the tender process for SOBO Department 21.
The tender documents were submitted to the invited contractors on September 14, 2020 and the bid should be delivered on October 7, 2020.

The result of the tender process was:
- Sustain Renewables: Evaluation point: 9.4
- Solarpark.dk: Evaluation point: 8.1
- Søgård Byg: Evaluation point: 4.6

Construction contract
Based on the result of the tender process, the company Sustainable Renewables was awarded the construction contract, which was signed on December 17, 2020.

4.3.2 Tender process for SAB Housing Association.

It was decided to organize a gathered tender process for 8 individual departments in SAB Housing Association: Department 13, 15, 18, 20, 22, 24, 27, 30.
The management of SAB decided to invite 3 companies to bid for installation of solar PV and battery systems for the 8 departments:

- Sustain Renewables A/S, 6400 Sønderborg
- Søgård Byg A/S, 6200 Aabenraa
- Solarpark.dk A/S, 6240 Løgumkloster

Tender documents
The engineering design company prepared the tender documents consisting of:

- Tender letter dated 09.07.2020
- Technical description.
- Drawing documents.
- Description of the actual buildings.
- Expected performance data for the systems in the 8 departments.
- Pricelist for the bids.

The tender was a Main Construction Contract including solar panels, batteries, installation of solar panels and batteries, all electrical installations and the carpenter work preparing the roofs for solar panels.

Evaluation process
The tender letter specified two evaluation criteria for the bids:

- The lowest price for the solar PV and battery installation
  This part of the evaluation counts 75%.

- The technical quality and the solar electricity production is evaluated from 0-10 points, and this part of the evaluation counts 25%

Results of the tender process for the 8 SAB Departments:
The tender documents were submitted to the invited contractors on July 9, 2020 and the bid should be delivered on August 13, 2020.

The result of the tender process was:

	Solarpark.dk	*Søgård Byg*	*Sustain Renewables*
Total price:	10.0 points	7 points	4 points
Quality and efficiency:	8.5 points	9 points	9 points
Weighed total points:	9.6 points	9 points	5 points

Construction contract
Based on the result of the tender process, the company Solarpark.dk was awarded the construction contract.

Tender process for SAB Department 21.
SAB Department 21 Rådmandsløkken has organized a complete construction contract with the company Sustain Renewables A/S. The contract includes consultancy, design and implementation of the solar PV and battery systems.
There are 6 separate buildings in the Department. The solar PV panels are installed on 3 of the buildings and combined with 3 battery solutions. Each of the 3 systems contributes solar electricity to 2 buildings.

4.4 Investment and feasibility of the involved Departments.

Department	Apartments	Investment	Saved electricity	Saved electricity	ROI
	No	Euro	kWh	Euro	Years
SAB - 13	93	340.000	105.000	30.000	11,3
SAB – 15	105	360.000	125.000	35.000	10,3
SAB - 18	114	410.000	120.000	34.000	12,0
SAB – 20	94	295.000	105.000	30.000	9,8
SAB – 21	72	385.000	85.000	24.000	16,0
SAB – 22	432	345.000	65.000	18.000	19,1
SAB – 24	324	925.000	330.000	93.000	10,0
SAB – 27	52	170.000	55.000	15.000	11,3
SAB – 30	232	420.000	250.000	70.000	6,0
SAB - Byg 2	Common	90.000	23.000	7.000	12,9
SOBO – 12	72	325.000	110.000	30.000	10,8
SOBO – 21	49	206.000	60.000	17.000	12,1
	1.639	4.271.000	1.433.000	403.000	10,6

Figure 4: Investment and feasibility of the involved Departments.

Average investment per apartment: 4,271,000 / 1,639 = 2,610 Euro.
Average investment per m2 apartment area: 4,271,000 / 127,600 = 33.5 Euro
Average electricity saving per m2 apartment: 403,000 / 127,600 = 3.2 Euro

4.4.1 ROI and Lifetime for Batteries.

The average Return of Investment (ROI) is calculated to 10.6 years.
However, the batteries in the systems are totally new developed batteries, and therefore, the lifetime for the batteries is unknown.
The depreciation period for the batteries is estimated to 5 years.

4.5 Approval from the Authorities

Implementation of solar PV and battery systems in Denmark demands approval from 3 authorities:

- Sonderborg Municipality regarding the Danish building codes.
- Danish Energy Agency regarding access to the public grid.
- N1 local electricity distribution company regarding the Danish electricity codes.

4.5.1 Danish Building Codes

The building owners have to document, that the bearing roof construction is strong enough to bear the extra load from the solar panels. However, the roof integrated solar panels replace the existing roof plates, and therefore the roof construction normally is strong enough to accept the load from the solar panels.

- - It also needs to be documented, that the fire protection around the batteries is save.
- - Finally the Municipality has to secure, that the local building plans for the specific neighborhood allows to change roof plates with solar panels.

4.5.2 Access to public grids

The governmental Danish Energy Agency needs to pre-approve the implementation of solar PV panels in order to allow access to the public grid. Before starting the implementation, the building owner has to wait for pre-approval of a specific size of the solar panels in kW.
Within 30 days after the implementation, the building owner needs to ask for a final approval by the Danish Energy Agency to allow connection to the grid for the specific size of solar panels.

4.5.3 Danish Electricty Codes

The local electricity distribution company N1 needs to supervise and approve the physical electrical installation and connection to the grid.

4.6 Implementation phase

After signing the contract with the winning contractors, the implementation phase has started.

Department	Street	Contracted date	Completed date
SAB - 13	Borgmesterløkken	23.04.2021	17.07.2021
SAB – 15	Klosterløkken	22.04.2021	25.07.2021
SAB - 18	Ryttervænget	28.01.2021	20.07.2021
SAB – 20	Vølundsgade	28.01.2021	05.06.2021
SAB – 21	Rådmandsløkken	01.12.2020	15.07.2021
SAB – 22	Kløvermarken	28.01.2021	28.08.2021
SAB – 24	Søstjernevej	09.07.2021	10.08.2021
SAB – 27	Primulavej	22.04.2021	26.07.2021
SAB – 30	Stenbjergparken	31.05.2021	05.08.2021
SOBO – 12	Grundtvigs Alle	25.03.2020	10.09.2020
SOBO – 21	Udsigten	17.12.2020	29.03.2021

Figure 5: Dates for contracts and completion

4.6.1 SOBO Department 12. Pictures below:

670 m^2 solar PV panels integrated in the roof combined with 70 kWh battery capacity. The batteries are installed in technical rooms outside the 3 buildings.

Department 12 has 72 apartments.

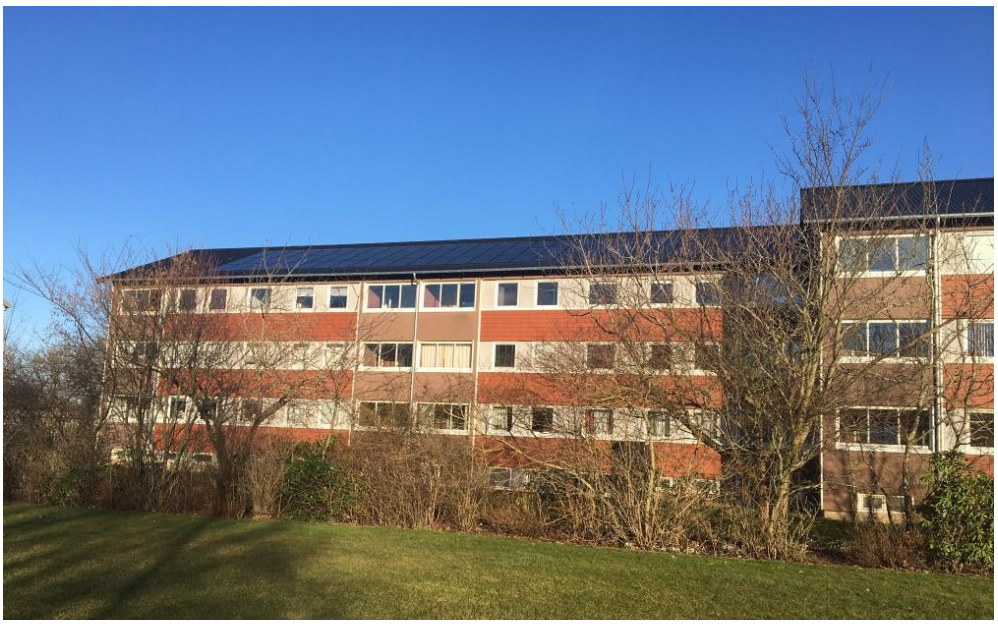

Figure 6: Solar PV panels integrated in SOBO 12

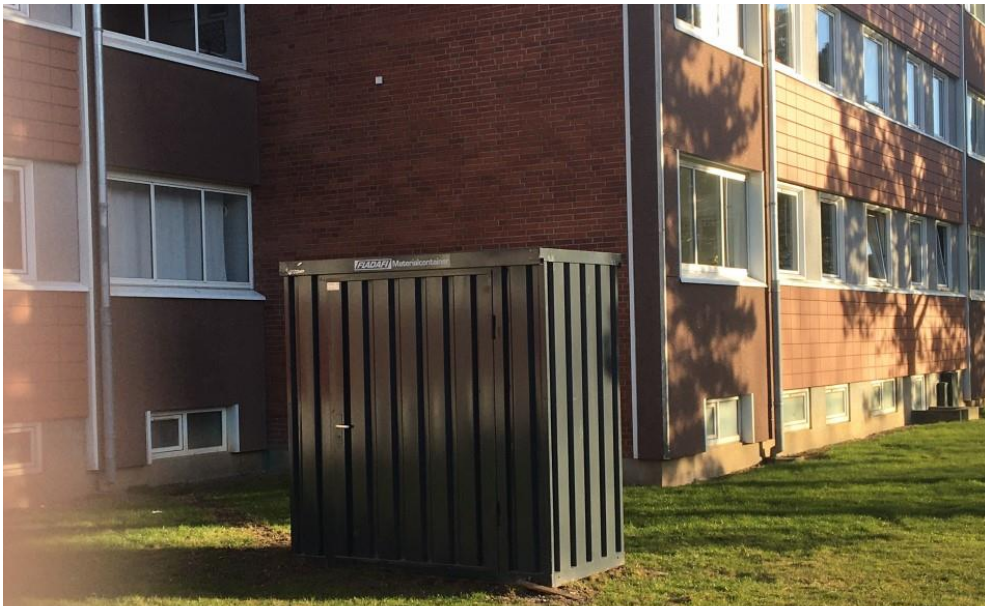

Figure 7: Battery storage installed outside the building in SOBO 12

4.6.2 SOBO Department 21. Pictures below:

350 m^2 solar PV panels integrated in the roof combined with 55 kWh battery capacity. The batteries are installed in the attic of one of the buildings.

Department 21 has 49 apartments.

Figure 8: Solar PV panels integrated in SOBO 21

4.6.3 SAB Department 13. Pictures below:

600 m^2 solar PV panels integrated in the roof combined with 60 kWh battery capacity. The batteries are installed in the technical rooms in the basement of each of the 3 buildings

Department 13 has 93 apartments.

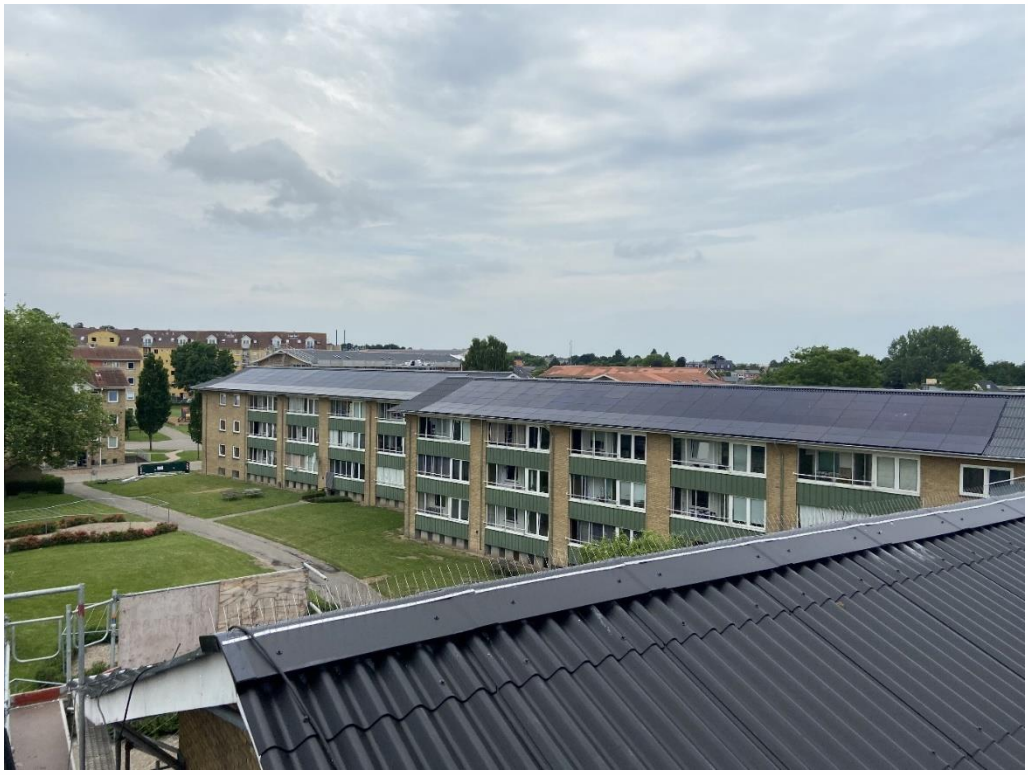

Figure 9: Solar PV panels integrated in SAB 13

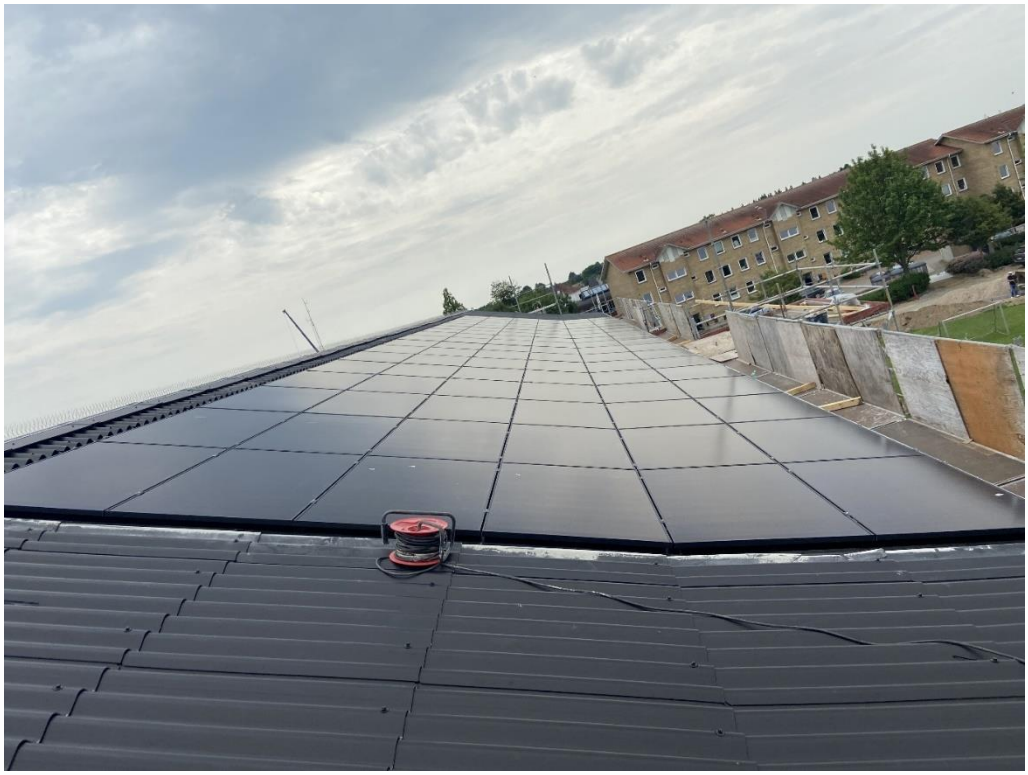

Figure 10: Solar PV panels in construction phase in SAB 13

4.6.4 SAB Department 15. Pictures below:

750 m^2 solar PV panels integrated in the roof combined with 80 kWh battery capacity. The batteries are installed in the technical rooms in the basement of each of the 4 buildings

Department 15 has 105 apartments.

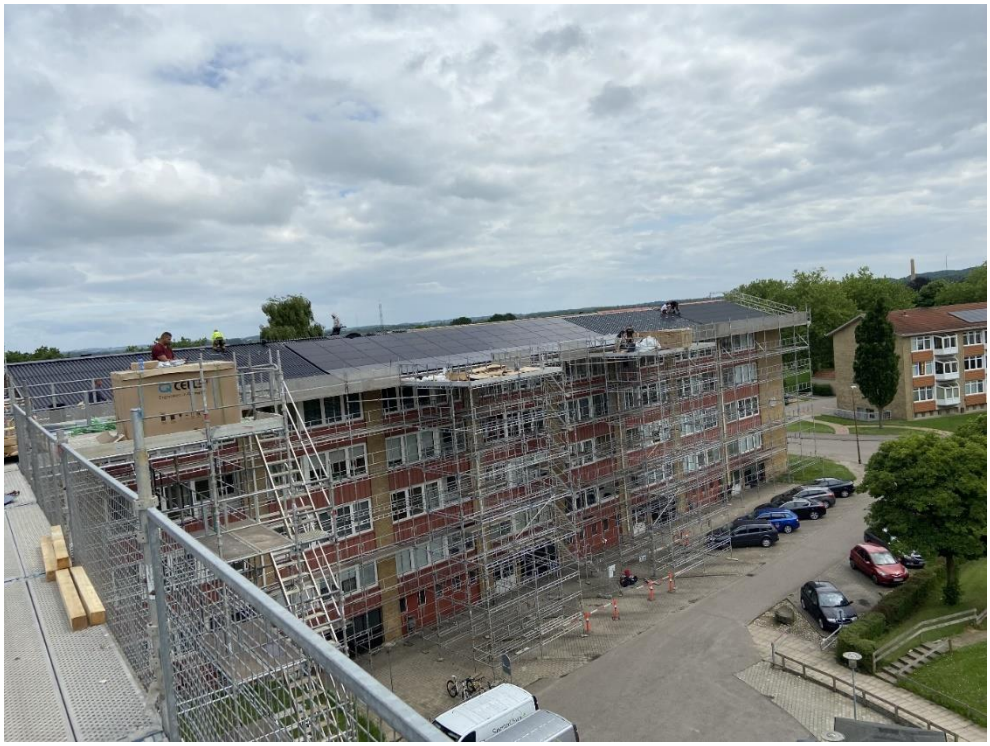

Figure 11: Solar PV panels in construction phase in SAB 15

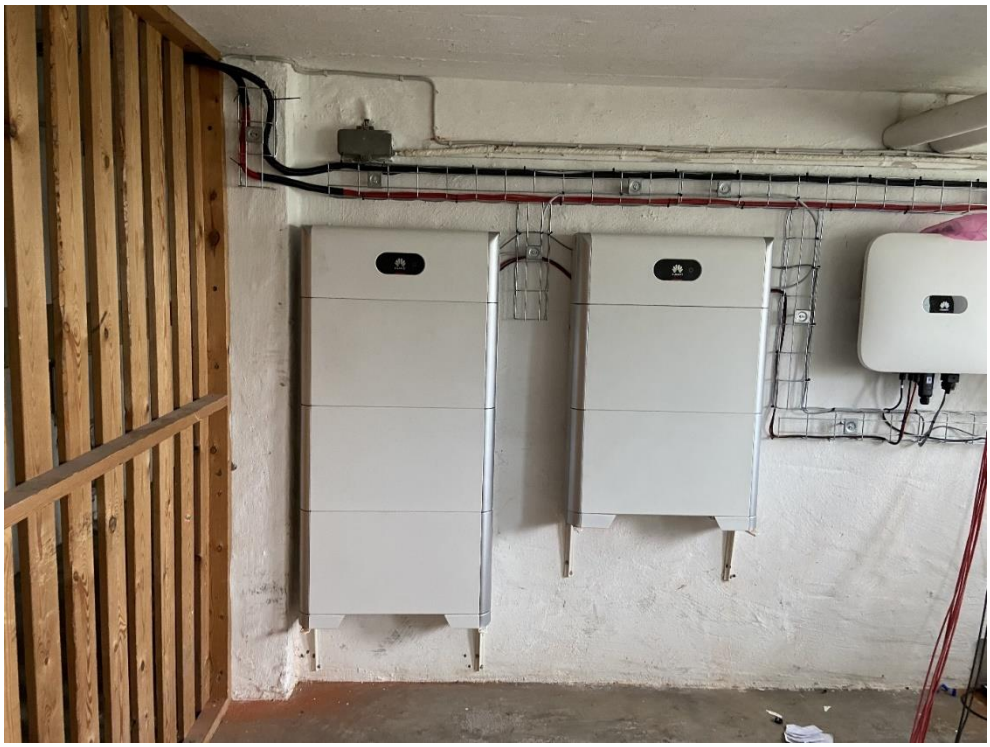

Figure 12: Battery systems in SAB 15

4.6.5 SAB Department 18. Picture below:

730 m^2 solar PV panels integrated in the roof combined with 75 kWh battery capacity. The batteries are installed in the technical rooms in the basement of each of the 4 buildings

Department 18 has 114 apartments.

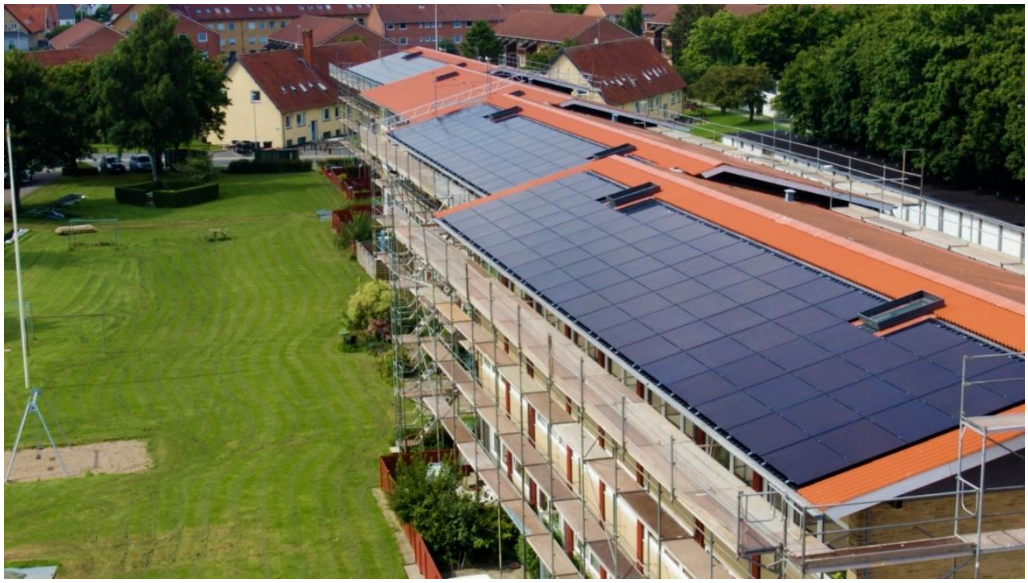

Figure 13: SolarPV panels integrated in SAB 18

4.6.6 SAB Department 20. Picture below:

600 m^2 solar PV panels mounted on the horizontal roof combined with 60 kWh battery capacity. The batteries are installed in the technical rooms in the basement of each of the 3 buildings

Department 20 has 94 apartments.

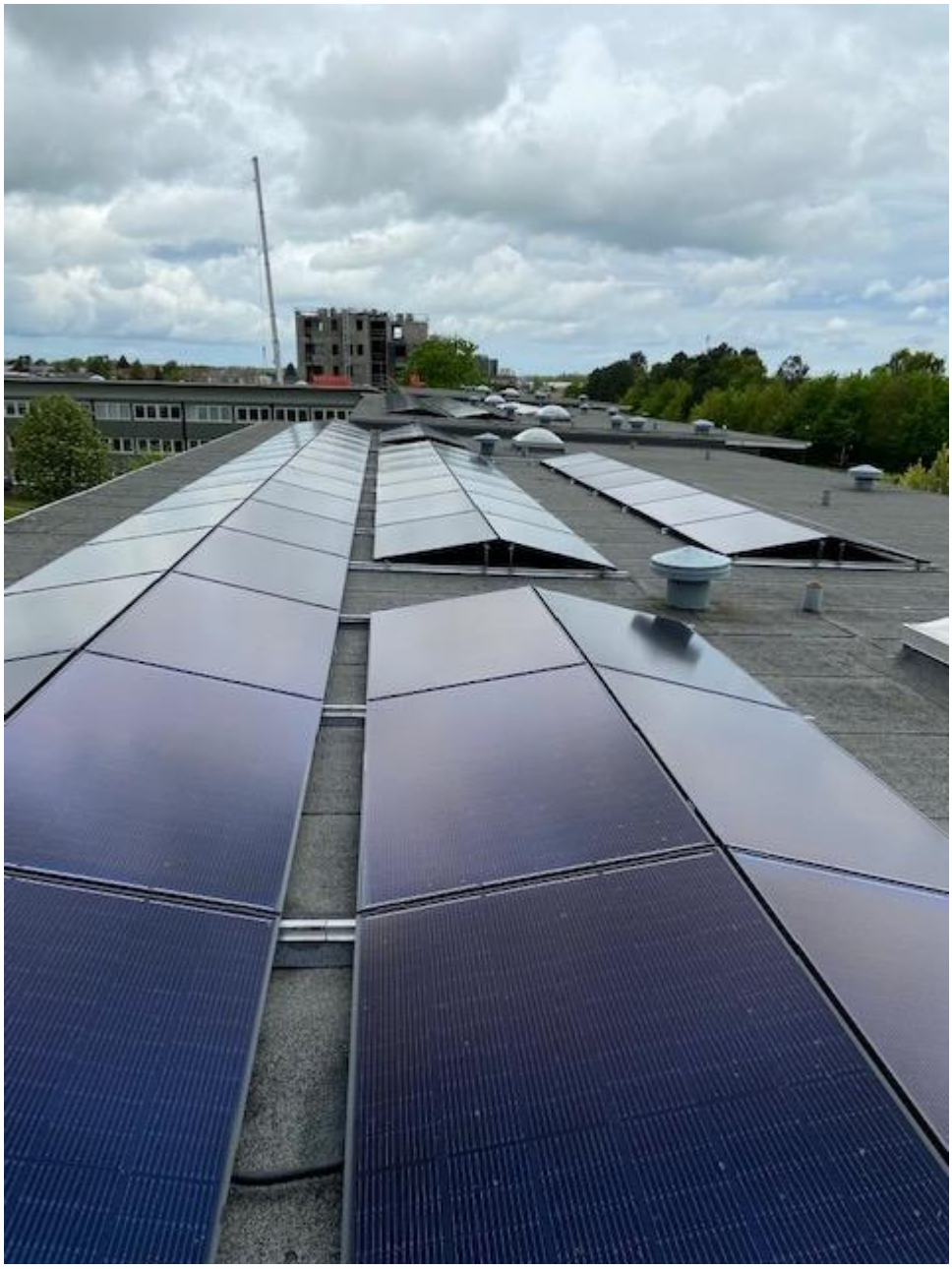

Figure 14: Solar PV panels installed on roof in SAB 20

4.6.7 SAB Department 21. Picture below:

500 m^2 solar PV panels installed on roof combined with 50 kWh battery capacity.

The batteries are installed in technical rooms outside the 3 buildings.

Department 21 has 72 apartments.

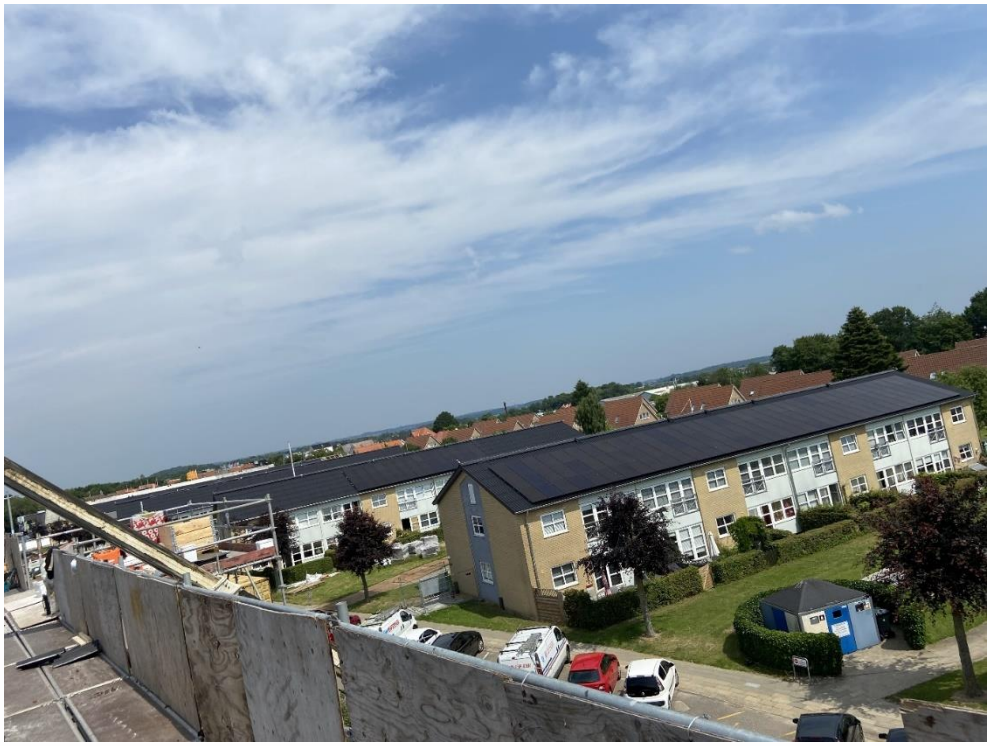

Figure 15: SolarPV installed as roof-top panels in SAB 21

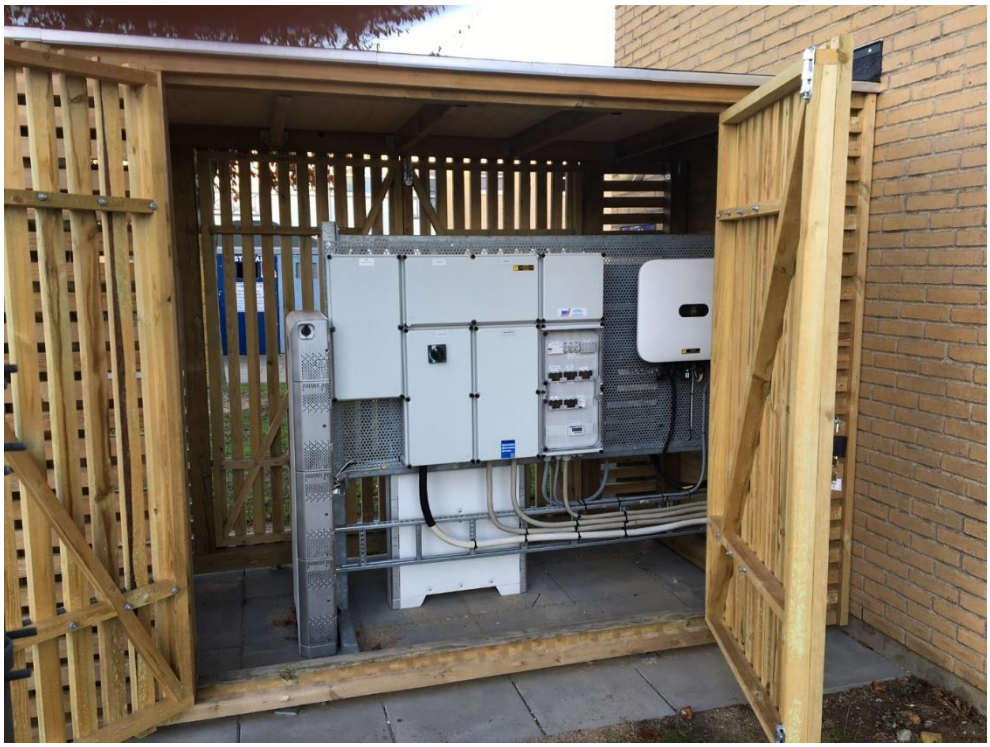

Figure 16: Battery and electrical systems installed outside the buildings in SAB 21

4.6.8 SAB Department 22. Pictures below:

3,000 m^2 solar PV panels integrated in roof combined with 290 kWh battery capacity.

Each of the 19 buildings has individual solar PV panels and a battery in the basement.

Department 22 has 432 apartments.

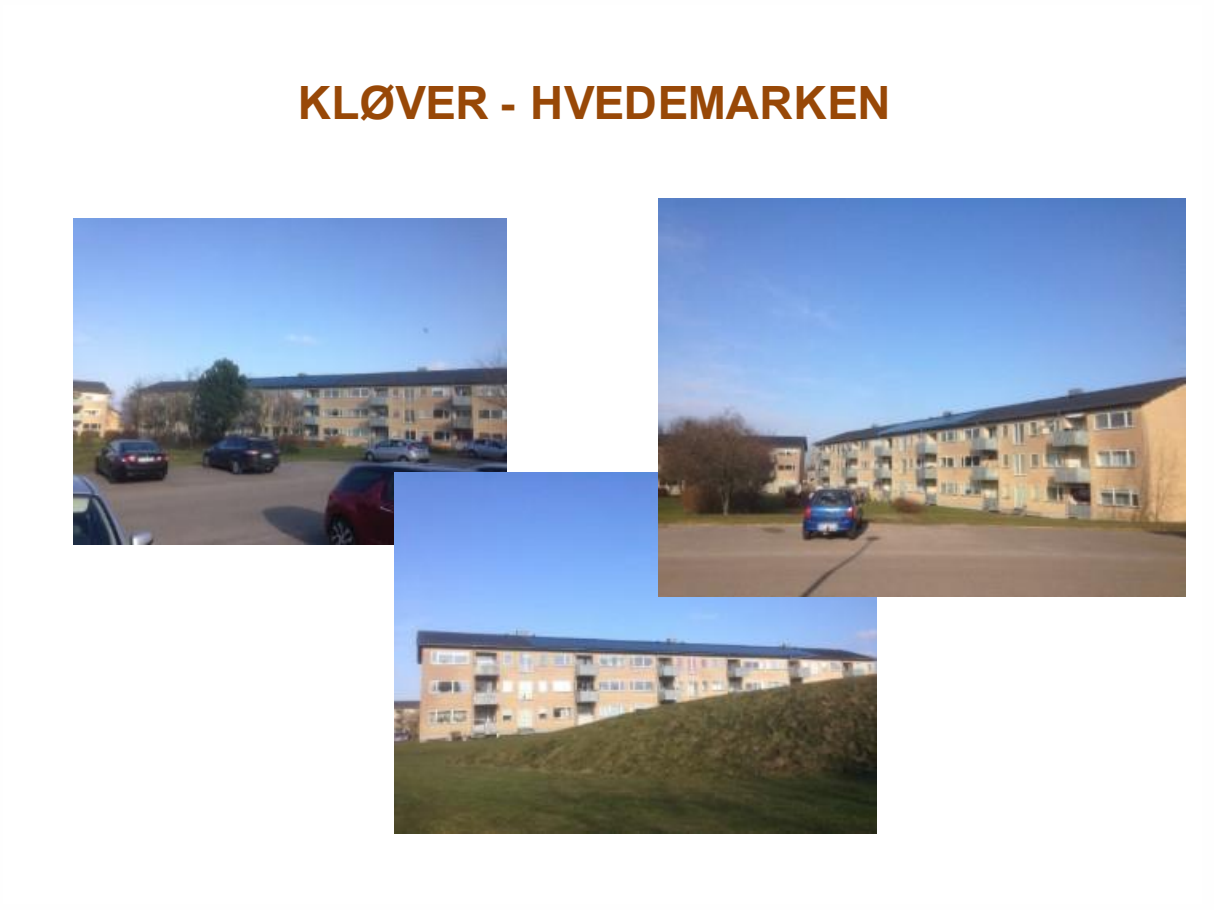

Figure 17: SolarPV panels integrated in SAB 22 back in 2017

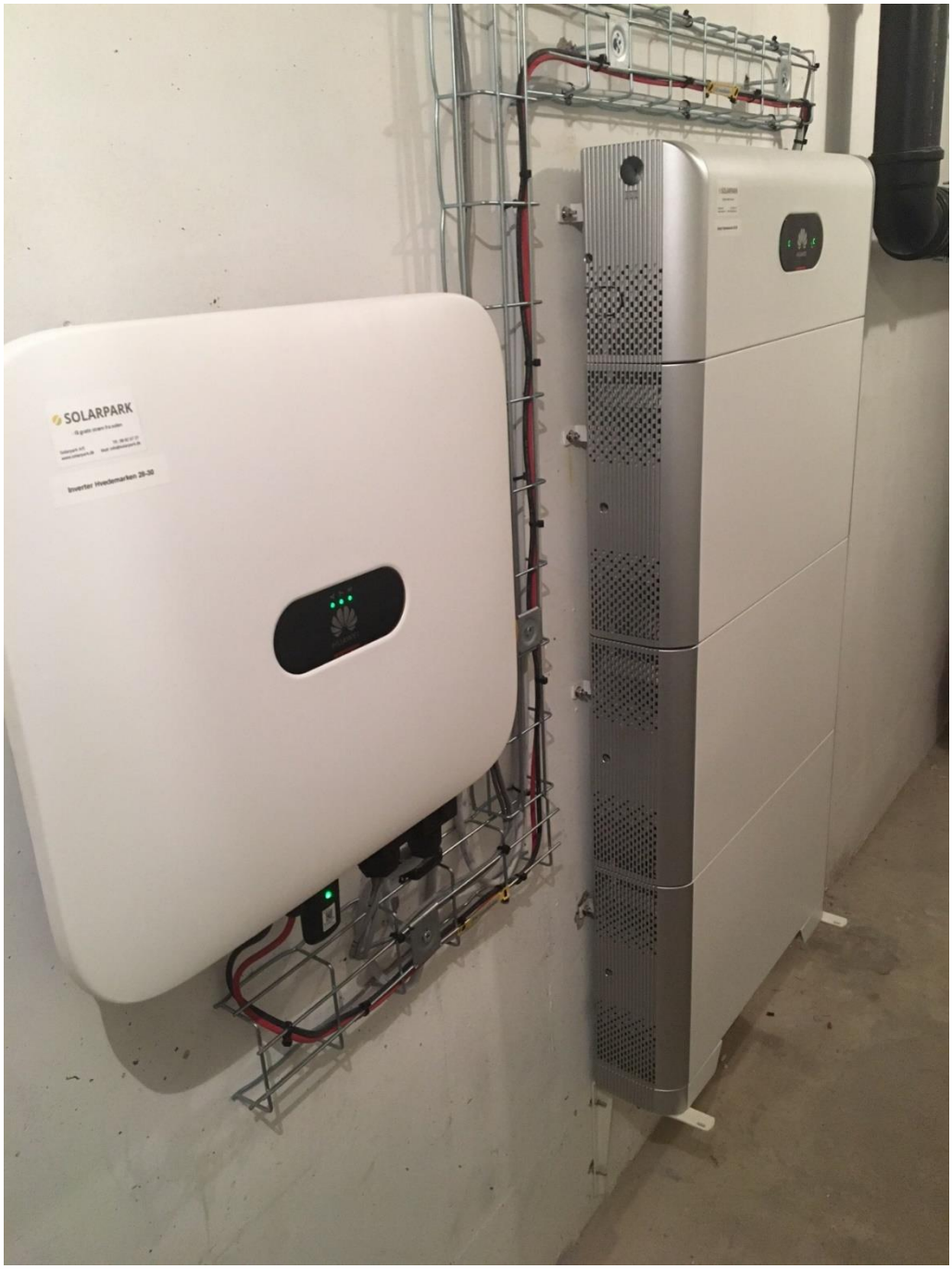

Figure 18: Battery systems installed in SAB 22 in 2021

4.6.9 SAB Department 24. Picture below:

1,870 m^2 solar PV panels integrated in roof combined with 200 kWh battery capacity.

Each of the 10 buildings has individual solar PV panels and a battery in the basement.

Department 24 has 324 apartments.

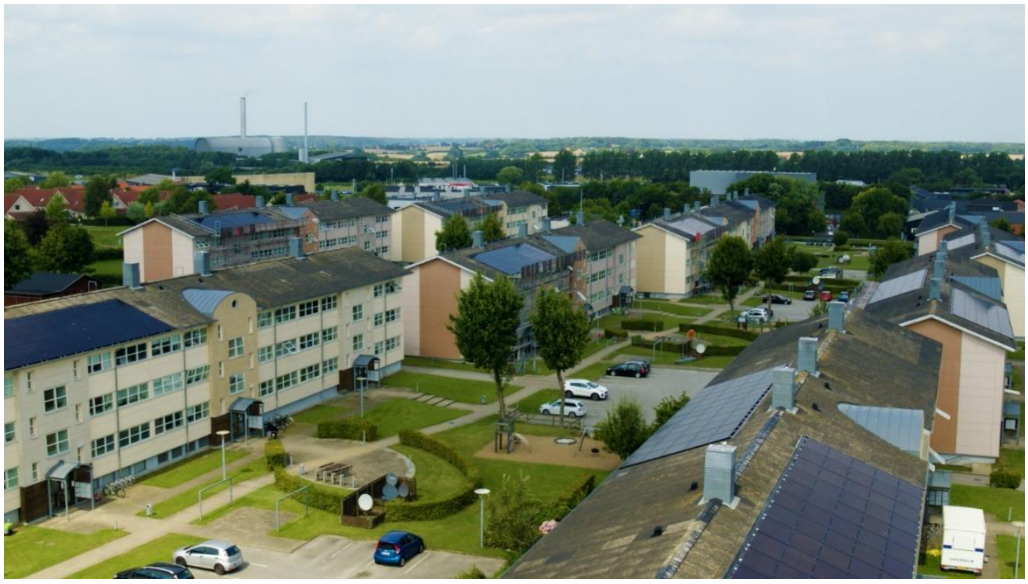

Figure 19: SolarPV panels integrated in 10 building in SAB 24

4.6.10 SAB Department 27. Picture below:

350 m^2 solar PV panels integrated in the roof combined with 30 kWh battery capacity. The batteries are installed in the technical rooms in the basement of each of the 2 buildings

Department 27 has 52 apartments.

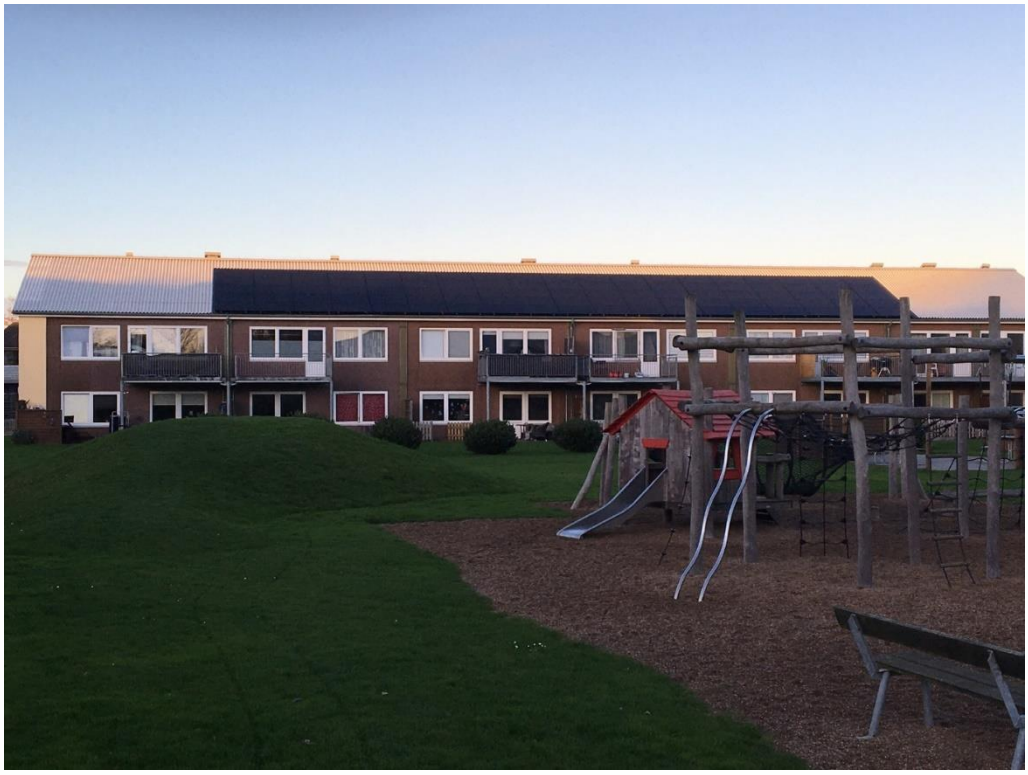

Figure 20: SolarPV panels integrated in SAB 27

4.6.11 SAB Department 30. Picture below:

1,650 m^2 solar PV panels mounted on the horizontal roof combined with 80 kWh battery capacity. The batteries are installed in the technical rooms in the basement of each of the 2 buildings

Department 20 has 232 apartments.

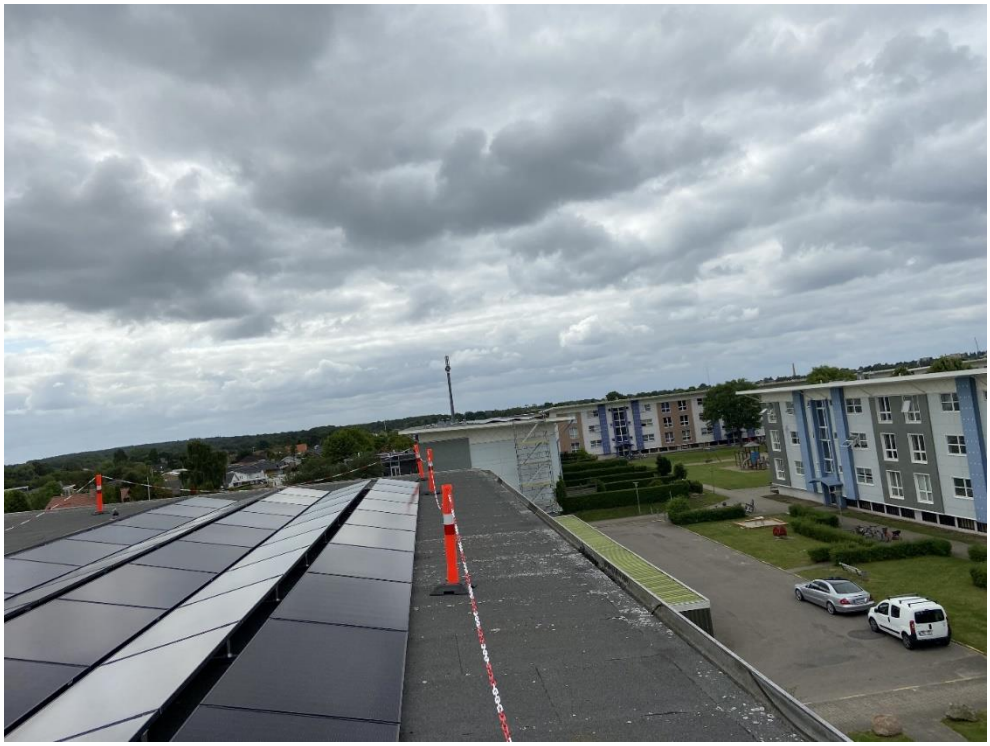

Figure 21: SolarPV installed as roof-top panels in SAB 30

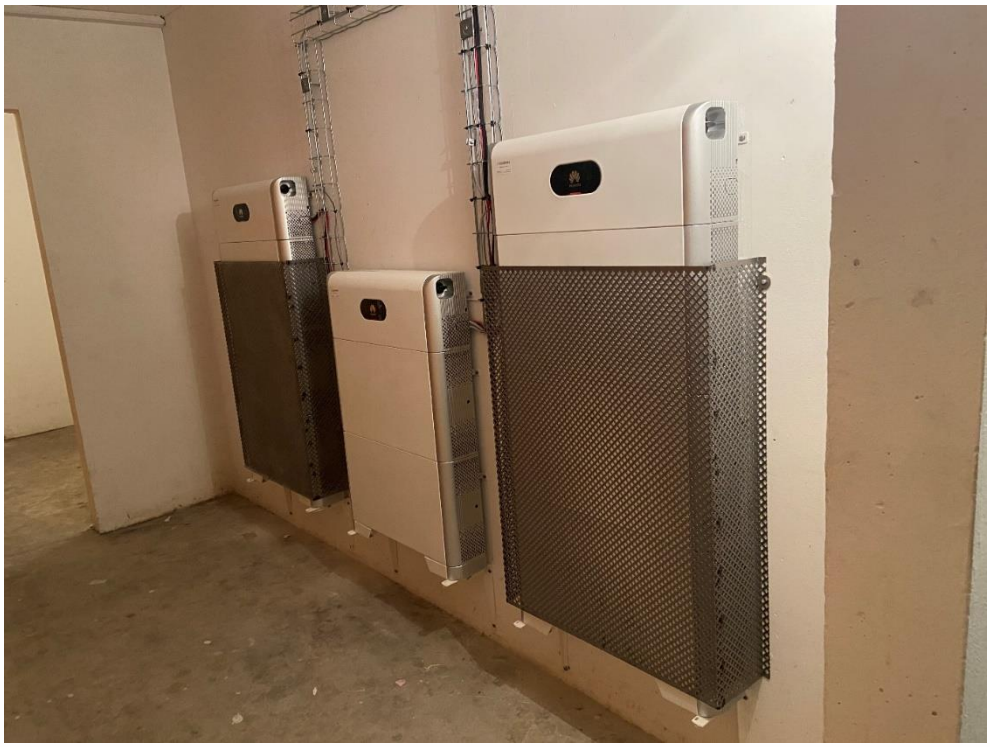

Figure 22: Battery systems in SAB 30

5 Approval and handover

After the completion of the construction phase the work has been approved by the housing associations and by the consultants The installed solar PV and battery systems have been connected to the electrical installations in the buildings and to the public grid to deliver the surplus produced solar electricity.
The solar systems have been designed to use 80 - 90 % of the produced electricity to the batteries in the buildings and to deliver maximum 20 % to the public grid.
There have been signed contracts with the electricity supply companies, how much they can pay for the surplus produced electricity from the solar plants.

5.1 Approach to monitoring the performance of the solarPV – battery systems

The performance of the solar PV-battery systems is monitored by the inverters in the systems, the solar PV inverter and the battery inverter.
The inverters monitor:

- Solar electricity produced and transferred directly to the building loads.
- Solar electricity produced and stored in batteries.
- Solar electricity transferred from the batteries to the buildings.
- Produced solar electricity transferred to the grid, because batteries are full charged.
- Necessary electricity transferred from the grid to the buildings, because batteries are empty.

The monitored data are stored in the inverters, and the data can be displayed and processed through access to a homepage (www) via login.

6 Deviations to the plan

The PV Battery storage project was part of Amendment 2 + 3. Implementation, therefore, was not completed until summer 2021, and actual savings will not be reported until 2022.

The original plan was to submit this deliverable D.5.5 by April 30, 2021 (Month 63).

7 Outputs for other WPs

N.A.

8 Annex

8.1 Technical data for the installed solar PV and battery products.

Depart.	Solar panel product	Panel power	Solar inverter product
SAB 13	Hanwha QCELLS Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-36KTL
SAB 15	Hanwha QCELLS Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-36KTL
SAB 18	Hanwha QCELLs Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-20KTL
SAB 20	Hanwha QCELLS Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-17KTL
SAB 24	Hanwha QCELLS Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-33 KTL
SAB 27	Hanwha QCELLS Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-15 KTL
SAB 30	Hanwha QCELLS Q Peak Duo G8 BLK	350 Wp	Huawei Sun2000-33KTL
SOBO 12	Jinko Solar JKM 315-M60	315 Wp	Kostal Inverter
SOBO 21	Axitec Solar Panel	330 Wp	SMA STP 25000 TL

Depart.	Battery product	Capacity	Battery inverter product
SAB 13	Huawei Luna2000-10-50	60 kWh	Huawei Sun2000-10KTL
SAB 15	Huawei Luna2000-15-50	80 kWh	Huawei Sun2000- 5KTL
SAB 18	Huawei Luna2000-10-50	75 kWh	Huawei Sun2000- 8KTL
SAB 20	Huawei Luna2000-10-50	60 kWh	Huawei Sun2000- 6KTL
SAB 22	Huawei Luna2000-15-50	290 kWh	Huawei Sun2000- 8KTL
SAB 24	Huawei Luna2000-10-50	200 kWh	Huawei Sun2000-10KTL
SAB 27	Huawei Luna2000-10-50	30 kWh	Huawei Sun2000- 8KTL
SAB 30	Huawei Luna2000-10-50	80 kWh	Huawei Sun2000-10KTL
SOBO 12	Smiles-Bat-LFP	70 kWh	Kostal Inverter
SOBO 21	BYD battery	55 kWh	SMA STP 25000 TL

8.2 Design process used to demonstrate the feasibility of solar PV storage projects in the approval process.

The calculations used to demonstrate the feasibility in the approval process for the tenants in the housing associations are based on the measured annual electricity consumption in the specific housing blocks.

Furthermore based on experiences from a public research project called “Boligejendomme med CO2-neutralt el-forbrug” (CO2 neutral electricity consumption in social housing associations).

This research project was funded by the Danish Ministry of Climate and Energy and published in 2017.

It was prepared by a consortium managed by COWI, the biggest consulting engineering company in Denmark.

The research project has analyzed solar cell plants combined with battery systems for 8 different solar housing associations similar to the housing association buildings used in Sonderborg.

The analyzes were based on computer simulations hour by hour during a Danish climatic reference year.

The result of these computer calculations shows, that the optimal size of solar panels in housing associations is 2,4 kWp per apartment.

The optimal size of battery storage in housing associations is analyzed to be 1,2 kWh storage capacity per apartment.

The optimal size of the combined system can cover about 50 % of the annual electricity

consumption in the apartment.

These calculations are based on an average of 3.140 kWh electricity consumption per apartment.

In the calculations for the solar-battery storage systems in Sonderborg, similar key-figures were used corrected to the actual electricity consumption in the specific housing apartments.

It turned out, that the average electricity consumption in Sonderborg is lower: 2.600 kWh per apartment, and the calculations are corrected according to that.

Based on key figures and actual electricity consumption the expected annual production from the solar-battery systems were calculated for each of the housing departments.

These calculations were the basis for the feasibility study presented and approved by the tenants in the housing associations in Sonderborg.

In the tender material to the invited suppliers, the housing associations did not require a specific size of solar panels and batteries.

The tender material indicated the consultants estimated size of components, but it was up to the suppliers to simulate and calculate, which combination of solar cells (in kWp) and batteries (in kWh) was optimal for their products in order to produce the expected amount of solar electricity per year.

8.3 Monitored data for the period 08.2021 – 06.2022

	SOBO (2 departments)	SAB (9 departments)
August 2021	20.200 kWh	157.130 kWh
September 2021	15.120 kWh	118.381 kWh
October 2021	10.080 kWh	78.873 kWh
November 2021	5.040 kWh	39.190 kWh
December 2021	3.360 kWh	26.526 kWh
January 2022	3.160 kWh	25.600 kWh
February 2022	8.400 kWh	65.647 kWh
March 2022	13.440 kWh	105.374 kWh
April 2022	20.100 kWh	135.700 kWh
May 2022	25.200 kWh	170.600 kWh
June 2022	21.800 kWh	147.900 kWh