Boligsosialt arbeid inn i fremtiden – testarena for ny Bodø

Tilskuddsmottaker: Gunvald Johansen Bygg AS

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Forfatter: Eivind Nygård, Gunvald Johansen Bygg AS

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1 Sammendrag/Summary

Deler av oppsummeringen er skrevet på engelsk siden hovedrapporten om energianalyse av boliger i prosjektet Sjøsiden er skrevet på engelsk.

Hovedfunnene i prosjektet er knyttet til energianalysen som viser hva som skal til for å endre planlagte TEK17-boliger i et tradisjonelt boligområde i Bodø til nullutslipps-bygninger, såkalt ZEB-O. Analysen viser at husene bør helst bygges med passivhusstandard for å oppnå ZEB-O. Gunvald Johansen Bygg har tidligere kalkulert passivhus og boliger som skal oppfylle passivhuskrav og det viste seg at det er vesentlig dyrere enn TEK17-boliger.

I tillegg gjør regelverket og definisjoner rundt fjernvarme at det er svært vanskelig å oppnå ZEB-O uavhengig av pris.

Prosjektet viser at teknologien som er tilgjengelig i dag ikke er tilstrekkelig effektiv for å kunne produsere nok strøm på tilgjengelig areal. I tillegg har dagens regelverk begrensninger som gjør at distribusjon av eventuell overskuddsenergi har klare begrensninger. Det er heller ingen økonomiske insentiver for nabolag å benytte lokalt produsert elektrisitet siden netteier krever samme pris for strømmen uavhengig om denne kommer fra nabobygget eller fra sentralnettet.

En del av prosjektet har vært å bedre dialog mellom offentlige og private aktører i bransjen knyttet til klimaspørsmål. Det har vært arrangert dialogmøte i Bodø og interessen og oppmøtet på møtet vitner om at denne type møter er svært viktige for både offentlige og private. Tilbakemeldingene fra møtet var at dette er noe bransjen ønsker videreført.

I rapporten vil man komme tilbake til de øvrige temaene og belyse disse nærmere.

Vedlagt denne sluttrapporten er energianalysen og invitasjon med deltakerliste til Dialogmøtet.

SUMMARY:

The municipality of Bodø has decided that the current city-airport will be moved further away from the city center by 2026. The planning for the new neighborhood at the current airport area is already ongoing. The ambition of "Ny by – ny flyplass" is a neighborhood where future technological and environmental-friendly solutions will be realized. However, this also means that the new buildings being built before 2026 ideally should use technologies and solutions that make it possible to couple those buildings with the new buildings in the neighborhood "Ny by – ny flyplass".

The work performed in this report is associated to the Sjøsiden project of Gunvald Johansen Bygg AS. The current report focuses on two tasks: (1) identification of building projects, typical technologies and installations to achieve plus energy houses or to reach the zero emission building (ZEB) or zero emission neighborhood (ZEN) ambition. The knowledge gained from previous projects can also be used for the case of Bodø (considering geographical characteristics for infrastructure and climate) to achieve the best results with regards to energy use and greenhouse gas emissions; (2) a pre-study of energy system concepts and a simplified evaluation of the energy use and energy harvesting with the help of simulation tools.

The review on previous building projects on plus energy buildings and ZEBs shows that it is of outmost importance to work towards a defined ZEB ambition level from the planning and design phase already. To achieve a zero emission balance, energy efficiency measures should be applied to a building to decrease the energy demand. Knowing the energy demand of a building, the on-site energy system to generate electricity or heat can be dimensioned to compensate for the imported energy. The literature review on ZEBs shows that a heat pump system is usually chosen as the local heating system, and on-site PV panels are chosen for electricity generation to compensate for energy imported to the building.

An energy system analysis has been performed for three buildings at the Sjøsiden neighborhood in Bodø. The three buildings are a single-family house, a two-family house and a row house. The energy systems

considered in the analysis are district heating (DH), combined heat-and-power (CHP) and a seawater heat pump (SWHP). The "reference" system is DH because by regulation there is an obligation to connect to DH if the infrastructure is in place. The performance of the systems is evaluated based on the annual energy use and resulting annual emissions of the buildings.

Table 1. *Annual energy use and emissions for the three investigated energy systems.*

Performance indicator	District heating	Biomass CHP plant	Seawater heat pump
Single-family building *(609 m^2 heated floor area)*			
Energy [kWh/m^2/year]	69	78	21
Emissions S1 [kgCO_2/year]	512	552	234
Emissions S2 [kgCO_2/year]	2183	2005	1714
Two-family building *(711 m^2 heated floor area)*			
Energy [kWh/m^2/year]	65	75	17
Emissions S1 [kgCO_2/year]	541	606	218
Emissions S2 [kgCO_2/year]	2164	2091	1599
Row house *(936 m^2 heated floor area)*			
Energy [kWh/m^2/year]	50	57	17
Emissions S1 [kgCO_2/year]	573	615	279
Emissions S2 [kgCO_2/year]	2494	2304	2048

The results show that the SWHP leads to a lower annual energy use for heating and to lower annual carbon emissions compared to the DH system and a CHP plant. The trend is similar for all three houses. The energy use for the CHP plant is higher than the energy use for the DH system because more energy has to be delivered to meet the same demand due to the lower thermal efficiency of the CHP plant. Two scenarios for annual carbon emissions, S1 and S2, are investigated It is shown that the total annual carbon emissions are very dependent on the choice of CO_2 factor. It can be seen in Table 1 that the total emissions for the CHP plant are higher than for the DH system for scenario S1, whereas they are lower compared to the DH system for scenario S2. This difference is due to the choice of emission factors and their respective ratio (S1: 12 vs. 18 gCO_2/kWh for solid biomass and electricity and S2: 50 vs. 132 gCO_2/kWh for solid biomass and electricity). The importance of the exported electricity generated from the CHP plant increases in S2.

On top of this, a case study is performed investigating different measures to "upgrade" a building from TEK17 to a ZEB-O, where ZEB-O means that the on-site generated electricity compensates for all emissions from the operational (O) phase during the lifetime of the building. Results of the case study are shown for the two-family house. In general, it has been found that the TEK17 building does not reach a zero emission balance for any of the three energy systems. Therefore, the envelope of the building has been improved to passive house standard, the efficiency of the PV panels has been increased from 17 % to 22 %, and the total PV area has been increased to achieve a ZEB. If a SWHP is used, it is almost sufficient to improve the building envelope and the PV efficiency. This is important for a residential area where space for more PV panels is limited. For the DH system or the CHP plant, it is not sufficient to only improve the building envelope and the PV efficiency, but it would also be required to increase the total PV area to generate enough electricity to compensate for the imported electricity (Figure 1).

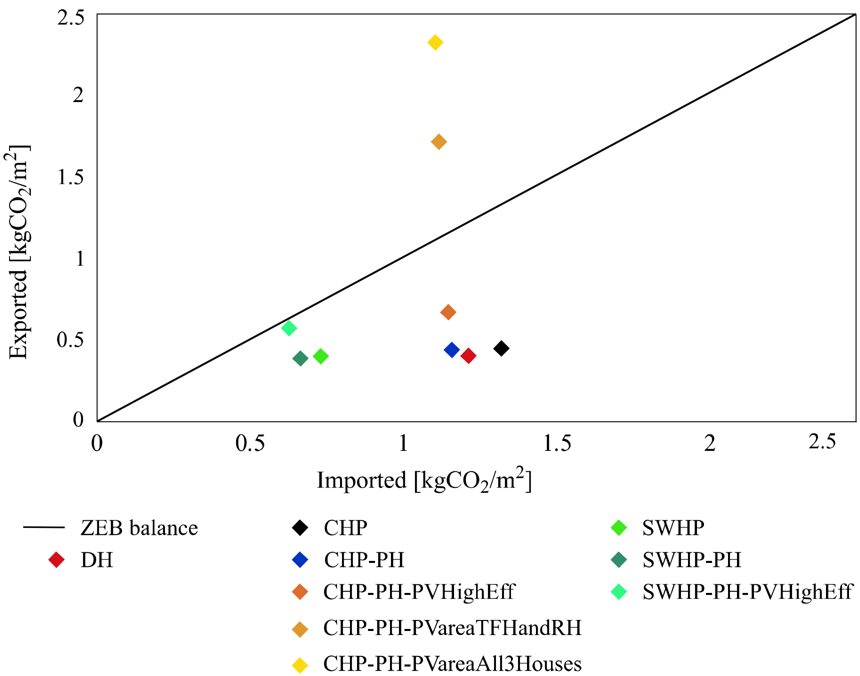


Figure 1. *ZEB balance for the two-family house to reach the ZEB-O ambition level.*

2 Innledning

Bakgrunnen for prosjektet er lokalt samarbeid mellom Husbanken i Bodø og Gunvald Johansen Bygg AS. Gjennom samtaler kom man fram til at her finnes det tema som begge parter ønsker å få kunnskap om. Selv om Husbanken og Gunvald Johansen er to helt ulike virksomheter med ulike oppgaver har vi et felles ønske: Å kunne tilby gode boliger til alle til en pris som er økonomisk bærekraftig. Økonomisk bærekraft i denne sammenheng er at utbygger får tilstrekkelig lønnsomhet men samtidig prises boligene slik at de er aktuelle for alt fra førstegangsetablerere til seniorer. Med gode boliger menes i denne sammenheng boliger som ligger i attraktive boområder, tilfredsstiller kundekrav men også er miljøvennlige.

Bærekraft i eiendomsutvikling er et tema som opptar ledelsen i Gunvald Johansen. Man har erkjent at Norge må gå foran i kampen for å begrense klimagassutslipp og siden omtrent 40% av klimagassutslipp kan relateres til bygninger er det viktig at bransjen tar ansvar.

Boligindustrien i Norge forholder seg til regelverk definert av offentlige myndigheter, så som «Plan og Bygningsloven» og «Byggteknisk forskrift», som oftest forkortet til TEK17. Det har så vidt vi kjenner til ikke blitt realisert nullutslipps boligområder i Nord-Norge og det var felles interesse fra Husbanken og Gunvald Johansen for å se nærmere på hva som skal til for å kunne realisere slike boligområder med forutsetning om at boligene skal være for alle, ref Nasjonal Strategi om «Bolig for velferd».

Som resultat av disse samtalene og felles målsetning sendte Gunvald Johansen Bygg søknad om tilskudd til boligsosiale tiltak med tilhørende prosjektplan med følgende hovedmål og delmål:

Utarbeide forslag til pilotprosjekt som kan bidra til å nå ambisjoner om bærekraftige og gode boligområder for alle i «Ny By», Bodø.

Delmål:

1. Etablere tettere dialog mellom offentlige myndigheter og private aktører i eiendomsbransjen
2. Kartlegging og utvikling av virkemidler som kan bidra til å nå hovedmålet:
3. Presentere konkrete piloter som kan testes på egne eiendommer i forkant av «Ny By».

3 Boligsosialt arbeid inn i fremtiden

3.1 Prosjektorganisering

Gunvald Johansen Bygg AS ved daglig leder Jørn Vidar Johansen har vært prosjekteier. Gunvald Johansen Bygg AS har også hatt prosjektlederrollen, denne har vært utført av prosjektutvikler Eivind Nygård. Øvrige ansatte i Gunvald Johansen har vært brukt som støttespillere i prosjektet.

John Clauß, forsker ved SINTEF Community i Trondheim, har jobbet med:

- Identification of technologies used to achieve a plus energy house or a ZEB
- Energy system analysis for Sjøsiden i Bodø

Samarbeidspartnere har i hovedsak vært:

- Bodø Kommune Nærings- og utviklingsavdelingen ved rådgiver Rakel Hunstad og kommunaldirektør Odd Henriksen.

- Husbanken ved seniorrådgiver Marit Iversen og avdelingsdirektør Lena Jørgensen
- Norconsult, Bodø Energi og Elektro-konsernet har vært positive bidragsytere i prosjektet

Framdriftsplan

Boligsosialt arbeid inn i fremtiden – testarena for ny by	Januar	Februar	Mars	April	Mai	Juni	Juli	August	September	Oktober	November	Desember	Januar '20	Februar '20	Mars '20
Fase 1: Oppstart															
Søknad kompetansetilskudd	x	x													
Engasjere prosjektleder for forprosjektet			x												
Planlegging av arbeidet				x	x										
Kartlegging av aktuelle samarbeidspartnere				x	x										
Fase 2: Utredning															
Innsamling av data fra ulike forskningsmiljøer, f eks FME ZEN/NTNU etc samt andre kompetansemiljøer innen relevante bransjer.									x	x	x				
Etablere møteplasser for offentlige og private aktører i bransjen, både enkeltstående og repeterende arrangement.					x	x	x	x	x	x	x	x	x		
Bearbeiding av data						x	x	x	x	x	x	x	x		
Fase 3: Utforming prosjektbeskrivelse															
Utarbeide modeller som kan testes i konkrete prosjekt.											x	x	x	x	
Fase 4: Formidling															
Presentasjon av funn og modeller														x	x

3.2 Mål, fokus og strategier

Prosjektets hovedmål har vært å *"utarbeide forslag til pilotprosjekt som kan bidra til å nå ambisjoner om bærekraftige og gode boligområder for alle i «Ny By» i Bodø kommune"*

Vi har i samarbeid med Sintef valgt en teoretisk tilnærmingsmåten for å vurdere hva som skal til for å kunne løfte klimaambisjonen for våre boliger fra å tilfredsstille TEK17 til å tilby nullutslippsboliger. Sintef har den nødvendige kompetansen og verktøy til å kjøre en avansert energianalyse basert på teoretiske 3D-modeller av bygningene. (ref vedlagte rapport)

Det har vært valgt å fokusere på boligområdet «Sjøsiden» siden dette prosjektet geografisk er sammenlignbart med området «Ny By» i Bodø kommune. Tomta er totalt ca 80 mål der omtrent halvparten er tidligere ubygd areal og halvparten har eldre næring og industribygg. Første utbyggingstrinn foregår på den ubebygde tomta som er relativt flat og grenser mot Saltfjorden i sør. Området var ferdig regulert i 2015, komplettert med en reguleringsendring i 2018. Man ser for seg en utbygging i området i flere etapper og over relativt lang tidsperiode.

I tillegg til energianalyse og vurdering av «Sjøsiden» har prosjektet vurdert nullutslipps bolighusprosjekt som har blitt realisert andre steder i landet. Sintef vært involvert i de fleste prosjektene på et eller annet nivå og det har vært av stor verdi for prosjektet vårt å samle empiri og erfaringer fra disse prosjektene. Felles for de tidligere prosjektene er at kostnadsnivået har vist seg å være for høyt til å kunne drive masseproduksjon av plussboliger. (ref vedlagte rapport)

Hovedfokus for prosjektet har vært å identifisere hvilke økonomiske, planmessige og eventuelt arkitektoniske konsekvenser overgang fra TEK17-bebyggelse til nullutslippsområde vil føre med seg. Definisjonen vi har benyttet til å definere nullutslippsboliger er ZEB-O, dvs klimanøytralitet i byggets driftsfase. (nærmere redegjort for i vedlagte rapport)

3.3 Økonomi

Det var søkt om tilskudd fra Husbanken i størrelsesorden 800.000,- mens tildelingen ble på kr 615.000,-

I forhold til budsjett så har utgiftsnivået vært noenlunde som forutsatt, ca 900.000,- mens egenandelen til Gunvald Johansen har vært høyere enn forutsatt. I budsjettfasen antok man en egenandel på 150.000,- mens regnskapet viser en egenandel på ca 260.000,-

Innkjøp av eksterne tjenester, i all hovedsak Sintef, var dyrere enn forventet. Det var på forhånd vanskelig å anslå kostnadsrammen på dette siden det var første gang vi har engasjert Sintef til en slik oppgave. Det er vanskelig å peke på et mer kompetent fagmiljø i Norge enn Sintef, og vi opplever at kvaliteten på arbeidet de har gjort for oss har vært av god verdi og avgjørende for prosjektet.

3.4 Delmål

3.4.1 Etablere tettere dialog mellom offentlige myndigheter og private aktører i eiendomsbransjen

Et av delmålene knyttet til dette prosjektet var å teste etterspørsel og behov for tettere dialog mellom offentlige og private aktører knyttet til eiendomsbransjen i Bodø kommune. Gjennom tett samarbeid med Nærings – og utviklingsavdelingen i Bodø kommune ble et knippe aktører invitert til dialogmøte 5. november 2019.

Temaet for møtet var «Hvordan nå ambisjonen om nullutslipps bygg – og boligområder?» Bakteppet for temaet var «Ny By – Ny Flyplass» som har høye miljøambisjoner. Prosjektet «Ny By» påvirker hele bransjen på en positiv måte i den betydning at flere av de store aktørene i Bodøs eiendomsbransje adopterer miljøambisjonene allerede nå og ønsker å nærme seg nullutslipp-visjonen i sine kommende prosjekt. Utfordringen er å finne en løsning på hvordan man kan nå visjonen uten at det går ut over den økonomiske bærekraften i prosjektene.

Til dialogmøtet var det invitert ledere i Bodø kommune, offentlige aktører som Bodø Energi, private utbyggere, private teknologiselskap og Avinor. Det ble også hentet inn to foredragsholdere fra Sintef som fortalte om FME ZEN (Forskningssenter for Miljøvennlig energi – Zero Emission Neighbourhood), hva som definerer et nullutslipps nabolag og orienterte om pågående pilotprosjekt.

Oppslutningen om dialogmøtet var formidabel, alle inviterte firma stilte med toppledere og tilbakemeldingene til initiativet var svært gode. På direkte spørsmål var også alle deltakerne positive til flere møter og det er i skrivende stund planer om et oppfølgingsmøte over nyttår. Kommende møter vil forhåpentligvis kunne inngå i en forlengelse av dette prosjektet dersom man får tilskudd til et oppfølgingsprosjekt.

Fra kommunens side var tilbakemeldingene at de svært gjerne ønsker private initiativ til slike møteplasser velkommen og ønsker å bistå ved eventuelle senere møter.

Den store fordelen med private initiativ er muligheten private aktører har til å handle og gjennomføre eksempelvis slike uformelle dialogmøter uten at man har det samme regelverk som kommuner og andre offentlige må forholde seg til.

I dialogmøtet «forpliktet» deltakerne seg til å dele informasjon med hverandre om relevante tema, samtidig som man fikk en bedre oversikt over hvilke prosjekt, strategier og teknologi sammenlignbare aktører har tro på og jobber med. Tilbakemeldingene var at opplegget fungerte etter hensikten, man kom «tett på» hverandre og fikk diskutert relevante problemstillinger samtidig som det ble klarere hvem som har ansvaret for hva i kommunen og kanskje spesielt Bodø Energi.

Energiforsyning er jo selve nøkkelen i problemstillingen rundt nullutslipp; det handler om å kunne produsere nok «ren» energi samtidig som energiforbruket minimeres. Bodø Energi sitter på mye kompetanse og en helt sentral nøkkelrolle som netteier og ble stilt mange spørsmål både i og utenfor møtelokalet. Møteformen med et begrenset antall deltakere som gjorde at man enkelt kunne henvende seg direkte til den man ønsket å snakke med og siden alle var forberedt fikk man gode svar og kunne gjøre avtaler om oppfølging av dialogen i etterkant av møtet.

Det var også en positiv side med møtet å kunne presentere Sintef for aktørene i Bodø. Det er etter vår forståelse få boligprosjekt i Bodø som tidligere har benyttet seg av kompetansen Sintef innehar. Antagelig har dette noe å gjøre med avstanden til Trondheim og usikkerhet hvem man skal kontakte og hva man kan bruke Sintef til, men blant annet som følge av dette dialogmøtet vet vi nå at kontakten har blitt opprettet med flere.

Invitasjon og deltakerliste er vedlagt.

3.4.2 Kartlegging og utvikling av virkemidler som kan bidra til å nå hovedmålet

Aktuelle virkemidler som har vært behandlet i prosjektet går i hovedsak på teknologi knyttet til energiforbruk og produksjon. For å oppnå nullutslipp i driftsfasen (ZEB-O) er det nødvendig å minimalisere bruken og maksimere produksjon av energi. I tillegg må energien som forbrukes være «ren» og man forutsetter at produsert energi er fornybar, til eksempel gjennom solcelle eller vindkraft.

Vindkraft har vi i dette prosjektet valgt å se bort fra siden det ikke er mulig å etablere vindkraft i boligområder i et slikt omfang at produksjonen vil være effektiv.

Solceller og muligheter for bruk av disse er omtalt i Sintef-rapporten. Dagens solceller er for dyre og har for lav effektivitet til å være kostnadseffektive i et boligfelt med tett bebyggelse. Det er i henhold til beregningene i Sintef-rapporten for lite takareal tilgjengelig for å kunne produsere tilstrekkelig med elektrisk kraft for å nå målet om ZEB-O selv om husene bygges som passivhus. Denne teknologiske utfordringen har man i Gunvald Johansen tatt innover seg og vi har gått inn som partner i et forskningsprosjekt på «Bygningsintegrerte solceller» med planlagt oppstart 2020 og varighet på 4 år. Prosjektet skal arbeide med to parallelle utviklingsløp:

- Forbedring og videreutvikling av dagens løsninger med et mål om å forbedre kostnadseffektivitet og teknisk ytelse.
- Utvikling av fremtidens nye og forbedrede løsninger, komponenter og materialer egnet for bygningsintegrasjon.

Målet for prosjektet er å utvikle tverrfaglig kompetanse for å kunne tilby:

- Materialintegrerte og systemintegrerte løsninger for bruk i tak og fasader
- Løsninger for montering på tak og i fasader
- Løsninger som har gode byggtekniske ytelser for fukt, regnsikring, kondens og snø
- Godt ventilerte løsninger som sikrer optimal virkningsgrad i modulene
- Standariserte løsninger med mulighet for prefabrikasjon og enkelt vedlikehold
- Bestandige og robuste løsninger med god levetid og lavt klimafotavtrykk
- Løsninger og materialer som gir rom for fleksibilitet og estetikk i det arkitektoniske uttrykket
- Løsninger som er kostnadseffektive og lønnsomme i hele verdikjeden
- Løsninger som er sikre, pålitelige og har gode branntekniske egenskaper
- Løsninger som er optimale for norsk vær og klima

Gunvald Johansen Bygg er èn av 6 private partnere i prosjektet. Vi vil bidra i arbeidsgruppemøter samt med nødvendig egenkapital inn i prosjektet.

I prosjektplanen er det også nevnt andre virkemidler som kan bidra til å nå hovedmålet:

- Effektivisering av byggeprosess:
  - Dette punktet er en kontinuerlig prosess som pågår uavhengig av Husbankprosjektet. Vi har valgt å legge hovedfokuset i denne rapporten på energianalysen og dermed har vi ikke behandlet dette temaet særskilt her.
- Endrede krav til bygg:
  - Vi har i energianalysen gjort funn som tyder på at man ikke kan nå kravet om nullutslipps boliger og boligområder med dagens regelverk uten at det går på bekostning av økonomisk bærekraft. Det er pekt på at lovgivning rundt fjernvarme og distribusjon av eventuell overskuddselektrisitet ikke gjør det mulig å nå definisjonen ZEB-O. I tillegg må boligene endres fra TEK17 til passivhus-standard for å nærme seg kravene. Det kan være at endring av krav og forståelse av definisjonene ville gjøre det mulig å nærme seg ZEB-O men erfaringsmessig vil endring av reglene være en lang prosess og det er et arbeid som dette prosjektet ikke har mulighet til å behandle.
- Effektiv utnyttelse av arealbruk til boligbygging:
  - Det er beskrevet i energianalysen at tilgjengelig areal på planlagte bygg i prosjektet Sjøsiden ikke er tilstrekkelig til å generere nok elektrisitet fra solcellepanel til å nå ZEB-O. Dersom man kunne begrense areal til f eks parkering og/eller felles lekeplasser i regulering og heller benytte arealet til solcelleinstallasjoner ville dette øke produksjonen av elektrisitet, men det er ikke gjort økonomiske beregninger av hvilke konsekvenser dette vil få for økonomien i prosjektet. Kravene til parkering og fellesområder er bestemt i Plan og bygningsloven samt kommunale planverk som Kommunedelplanens Arealdel og eventuelle endringer må utredes og behandles politisk før dette kan vedtas.
- Kan teknologi bidra til at folk kan bo lenger i egen bolig?
  - Svaret er sannsynligvis ja, men i dette prosjektet har vi fokusert på energianalyse og ikke behandlet temaet konkret.

3.4.3 Presentere konkrete piloter som kan testes på egne eiendommer i forkant av «Ny By»

Resultatene fra prosjektet viser at vi med dagens teknologi ikke har mulighet til å bygge ZEB-O bygninger uten at det går på bekostning av den økonomiske bærekraften i prosjektet. Det har også vist seg vanskelig å nå ZEB-O med dagens regelverk knyttet til fjernvarmekonsesjon og definisjonen av utslipp knyttet til denne oppvarmingsmetoden. Sammenlignbare land som f eks Danmark har en annen energifaktor for fjernvarme enn Norge. NVE definerer fjernvarme med 30% fossil/el-andel mens Danmark endret sin definisjon av fjernvarme i 2018.

Prosjektet Sjøsiden ligger innenfor konsesjonsområdet til fjernvarme i Bodø og har tilknytningsplikt men ikke bruksplikt. Det er uansett slik at man da må ta en eventuell kostnad med anleggsbidrag for å tilknytte seg fjernvarmenettet og dersom man ønsker å gå for en løsning som gir bedre uttelling på CO_2-regnskapet må man ta kostnaden det er med å etablere en alternativ oppvarmingskilde, eksempelvis varmepumpe basert på bergvarme eller sjøvarme. Dette gir utslag i økte kostnader for prosjektet og går naturlig nok utover den økonomiske bærekraften i prosjektet.

Oppsummert så vurderes situasjonen dithen at det er forbundet med for stor økonomisk risiko å skulle bygge boliger som tilfredsstiller ZEB-O-kravene på Sjøsiden når man på forhånd vet at disse boligene vil bli vesentlig dyrere enn øvrige boliger i markedet. Med dagens teknologi og regelverk vil sannsynligvis disse boligene bli nok et eksempel på prototyper bygget for en kundegruppe med spesielt stor interesse for slike boliger (og tilsvarende stor betalingsevne) men erfaringer fra andre slike prosjekt gir et sterkt signal om at slike prosjekt ikke er økonomisk bærekraftig verken for utbygger eller kundene.

3.5 Resultater

3.5.1 Hovedmål

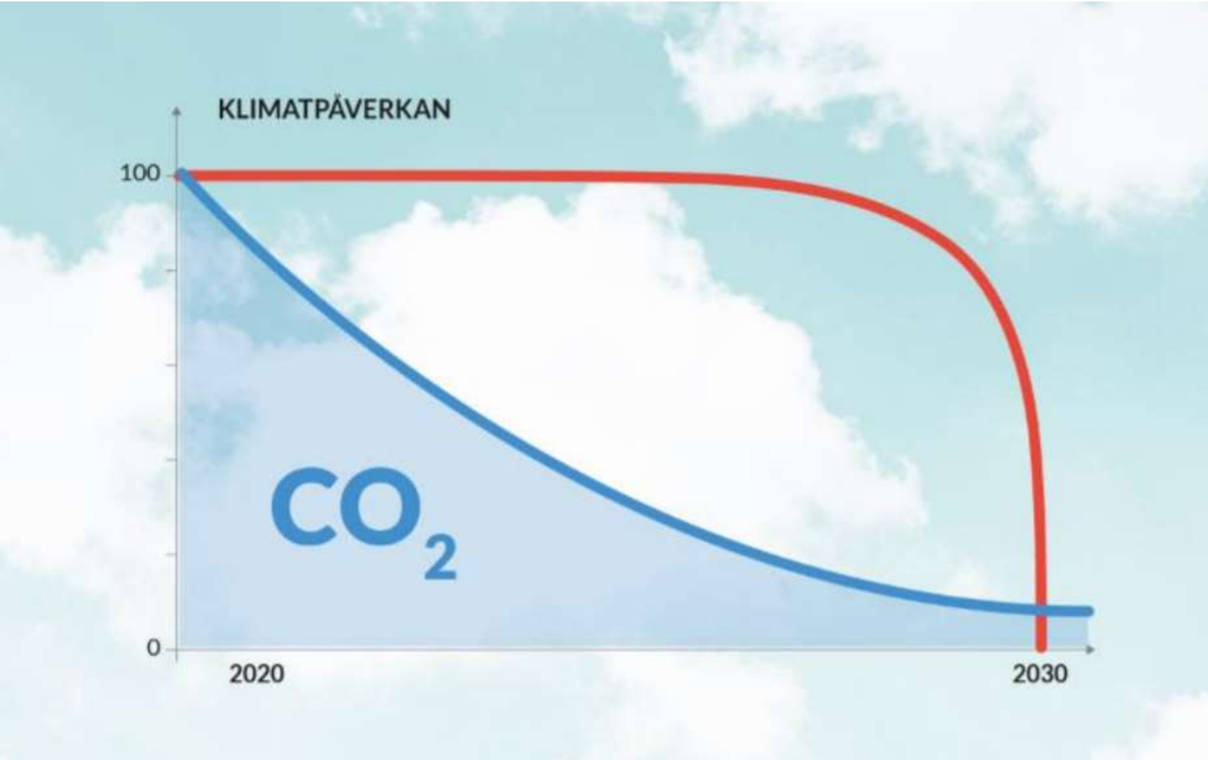
Hovedmålet har vært å se på hva som skal til for å gjøre plussenergiboliger tilgjengelig for alle, og ikke bare de som har spesiell interesse for temaet og spesielt god råd. Prosjektet har beregnet hva som skal til for at vanlige boliger som planlegges for salg på Sjøsiden kan bli ZEB-bygning, det vil si produsere mer energi i løpet av bygningens levetid enn den produserer iht definisjonen som er redegjort for i vedlagte rapport fra Sintef.

Man har sett på ulike tilnærmingsmåter med ulike energiforsyninger på et teoretisk nivå, ref Sintef-rapporten. Basert på Sintefs funn kan man fastslå flere utfordringer i forhold til å kunne nå målet om nullutslipp til alle:

- Dagens regelverk med fjernvarmekonsesjon er en hemsko for å bygge nullutslippsboliger siden fjernvarme har et betraktelig dårligere energiregnskap enn varmepumpeteknologi.
    - Dette behandles nærmere i vedlagte rapport fra Sintef
- Virkningsgrad til dagens kommersielle solcellepaneler ligger i beste fall på rundt 22% og tilgjengelig areal til solcellepanel er ofte for limitert til å forsyne tilstrekkelig med strøm for å påvirke energiregnskapet tilstrekkelig i positiv retning.
    - Dette behandles nærmere i vedlagte rapport fra Sintef
- Dagens regulering av kraftmarked vanskeliggjør full utnyttelse av produsert kraft siden det er lagt begrensninger på videresalg av produsert strøm i de perioder det produseres overskudd.
- Med dagens teknologi på solcellepanel vil husene måtte oppgraderes fra TEK17 til passivhusstandard – en fordyring av byggekostnad på ca 10 - 15%. (NB! Dette betyr ikke at husene er 10-15% dyrere for sluttkunde siden blant annet tomtekostnad ikke påvirkes av om huset er passivhus-standard eller ikke).
    - Dette behandles nærmere i vedlagte rapport fra Sintef

Konklusjonen i forprosjektet er at det ikke vil være mulig å tilby nullutslipps boliger til priser sammenlignbare med dagens TEK17-boliger og at det må utvikles teknologi som er mer effektiv, man må vurdere andre løsninger enn fjernvarme samt at regulering av områder og regelverk knyttet til distribusjon av elektrisk kraft må endres for at man skal nærme seg en økonomisk bærekraftig løsning.

Selv om konklusjonen i prosjektet kan virke negativ med tanke på hva som er målsetningen og ambisjonen til «Ny By» mener vi det er en viktig lærdom å ta med videre. Vi har erfart at det er fokus på regelverk og definisjoner og at bransjen, så vel offentlige aktører som private, jobber med løsninger som skal løse utfordringer knyttet til både regelverk og teknologi. Samtidig er det viktig å ha med seg at man ikke må unnlate å gjøre forbedringer selv om man kanskje ikke når målet om å kunne definere boligprosjekt som ZEB eller ZEN. Grafen under var vist under *1st Nordic Conference on Zero Emission and Plus Energy Buildings* i Trondheim i november 2019. Den viser at det er en stor gevinst i å redusere klimagassutslipp i årene fram mot nullutslippssamfunnet selv om man ikke når definisjonen nullutslipp med en gang. Sannsynligvis vil teknologien utvikles i stor fart videre, og det som kan virke som små steg i dagens prosjekt kan vise seg å være svært viktig med tanke på den framtidige målsetningen om nullutslipps-visjonen.



Anna Denell, Hållbarhetschef Vasakronan

3.5.2 Delmål – etablering av tettere dialog mellom offentlige og private

Det er stor interesse for temaet og både offentlige og private aktører i bransjen er involvert i ulike prosjekt. Deling av informasjon og debatt rundt ulike løsninger for å nå felles mål er noe både vi og andre bransjeaktører ser som særdeles viktig.

Husbankprosjektet initierte i samarbeid med Bodø kommune til et dialogmøte 5. november 2019 der formålet var reell informasjonsdeling blant bransjeaktørene. Deltakerne var «håndplukket» og ble personlig kontaktet og invitert. Gledelig nok var responsen overveldende positiv. Ingen av de forespurte takket nei til å delta og alle var glade for initiativet.

Konklusjonen for dette delmålet er at det er positivt at private aktører kan ta initiativ til slike møter. Det offentlige har visse begrensninger som gjør at det er vanskelig for dem å «håndplukke» deltakere i samme grad som private. Det at private står som arrangør gjør at vi tror det er enklere for private utbyggere å delta siden arrangøren forstår deres situasjon og utgangspunkt.

4 Conclusions and prospects for further work

This part focuses on two tasks:

1) the identification of previous building projects and their installed technologies to achieve plus energy houses or zero emission buildings (ZEB). The insights gained are used in task 2,
2) performing an energy system analysis for the specific property of Gunvald Johansen AS, Sjøsiden in Bodø. Three energy systems have been studied for three specific buildings, namely district heating (DH), combined heat-and-power (CHP) and a seawater heat pump (SWHP) for a single-family house (SFH), a two-family house (TFH) and a row house (RH).

The review on previous building projects on plus energy buildings and ZEBs shows that it is of outmost importance to work towards a defined ZEB ambition level from the planning and design phase already. To achieve a zero emission balance, energy efficiency measures should be applied to a building to decrease the energy demand. Knowing the energy demand of a building, the on-site energy system to generate electricity or heat can be dimensioned to compensate for the imported energy. The literature review on ZEBs shows that a heat pump system is usually chosen as the local heating system, and on-site PV panels are chosen for electricity generation to compensate for energy imported to the building. Regarding costs, a heat pump system combined with PV panels has higher investment costs than for example connecting a building to a district heating network, but operational costs are lower for a heat pump system and thus the system amortizes after a couple of years also leading to lower global costs.

With regards to zero emission neighborhoods (ZEN), the presence of ZEBs in a neighborhood is vital to achieve a zero emission balance for the whole neighborhood. Moving from the building-level to the neighborhood-level, system boundaries for the emission balance change. Not all buildings in a neighborhoods need to be ZEBs or plus energy buildings, but some (especially existing) buildings can be "normal" buildings that do not have on-site electricity generation (for example). Regarding the energy system, the integration of buildings into the (existing) infrastructure of the neighborhood is an important point. This is not a trivial task because energy system infrastructure might or might not be in place, and if new local infrastructure has to be installed, the buildings to be connected to the new infrastructure have to be ready for it. For example, if a local heating grid (LHG) is to be used, the energy supply system has to be designed for the temperature levels (supply and return temperatures) of the heating grid and furthermore, the heat distribution systems in the buildings have to fit the temperature level of the LHG. This is one of the reasons, why the planning and design phase becomes more important in the process of establishing zero emission neighborhoods.

An energy system analysis has been performed for three buildings at the Sjøsiden neighborhood in Bodø. The energy systems considered in the analysis are DH, CHP and a SWHP. The "reference" system is DH because by regulation there is an obligation to connect to DH if it the infrastructure is in place. The performance of the systems is evaluated based on the annual energy use and resulting annual emissions of the buildings. On top of this, a case study is performed investigating different measures to "upgrade" a building from TEK17 to a ZEB-O. Results of the case study are shown for the TFH exemplary. It has been found that the TEK17 building does not reach a zero emission balance for any of the three energy systems. Therefore, the envelope of the building has been improved to passive house standard, the efficiency of the PV panels has been increased from 17 % to 22 %, and the total PV area has been increased to achieve a ZEB. Confirming findings from literature review, it is found that the SWHP reaches the zero emission balance easier than DH or a CHP plant. If a SWHP is used, it is almost sufficient to improve the building envelope and the PV efficiency. From a practical point-of-view and based on the ongoing development of PV efficiency, cost-effective PV panels with an even higher efficiency will be available in the (near) future, so that the zero emission balance of the case study building could be achieved by installing highly-efficient PV panels. This is important for a residential area where space for more PV panels is limited. For the DH system or the CHP plant, it is not sufficient to only improve the building envelope and the PV efficiency, but it would also be required to increase the total PV area to generate enough electricity to compensate for the imported electricity.

A few issues and questions that could be investigated in future projects are:

- ***Building operation:***
    - In this project, the energy systems are evaluated for each building separately. With regards to interaction between buildings in a neighborhood, it is recommended to integrate the buildings into one energy system to evaluate the energy use of the buildings combined. This will be important when the focus is on the exchange of surplus electricity between buildings and thus feasible operation strategies.
    - Different operation strategies of the energy systems during operational phase are not considered in this project, but it is important to think about desired goals of operation strategies of the energy systems. More detailed thoughts are summarized in section 3.3.4 of this report.
- ***Regulations, business models and costs:***
    - National or municipality regulations, costs and business models go hand-in-hand as they often influence each other.
    - With regards to the choice of energy systems, what can local entrepreneurs do, if the new buildings are situated in a concession area for DH?
    - With regards to achieving a ZEB or ZEN, was is possible to attribute more public space to PV panels rather than green area? If so, how would that be accepted by inhabitants?
    - How does the local zoning plan consider the businesses of entrepreneurs? For example, if ZEBs are to be built instead of TEK17 buildings, extra insulation in the walls should be installed to decrease building heating needs which leads to thicker walls. If more insulation is put on the inside, living area is decreased and thus sellable living area. Current building are often rather narrow, so that it could not be functional to decrease the apartment width even more. If the insulation is to be put outside, the dimensions of the buildings increases, but the distance between the buildings still has to be kept according to the zoning plan. If many buildings are to be built, it could be necessary to adjust the zoning plan accordingly because otherwise, the increased building dimensions comes at the cost of decreased public area. This problem should ideally be considered during the planning phase already so that architect can take it into account.
    - Regarding costs and business models, who is owning what in the energy system? If a local heating grid is to be built, who is responsible for operating and maintaining it? Who takes the investment costs for a new energy system? If a heat pump supplies heat to a local heating grid, who owns and operates the heat pump? Who owns on-site PV panels, what is the payback time and who gets the possible savings from sold PV electricity?
    - What is the value of the energy systems from a private economic and public economic point of view? If there is an obligation to connect to district heating, is it feasible to built a local heating grid and operate a heat pump to supply heat?
    - Starting from the ZEB definition how can the ZEN definition be adjusted to also consider district heating as a more feasible technology for heat supply. For now, the ZEB balance is purely energy-based and thus favors the technologies that use the least energy to cover the demand.

Invitasjon til dialogmøte mellom private og offentlige aktører i bygg og anlegg
Hvordan nå ambisjonen om nullutslipps bygg og boligområder?

Tid/sted: Tirsdag 5.11.2019, kl. 08.00 – 11.00, på Scandic Havet, møterom i 1. etasje til høyre når du kommer inn hovedinngangen.

Det serveres lunsj til de som ønsker fra kl 11.00.

Formålet med møtet

I. Dialog mellom offentlige og private aktører om hvordan man kan nærme seg ambisjonen om nullutslipps boligområder/områder med blandet formål i ny bydel, i tråd med regjeringens mål om å fremme omstilling av Norge til et lavutslippssamfunn i 2050[1].
II. Reell deling av informasjon om klima-, energi- og miljøambisjoner hos den enkelte aktør, og hvilke teknologier man har evaluert, hvilke man jobber mot og hvilke utfordringer som fins.
III. Deltakere må ha et reelt ønske om å bidra til å finne løsninger som kan være bærekraftige både med tanke på klima, miljø, energiløsninger og økonomi.

Alle inviterte er sentrale aktører i Bodø og har ganske sikkert tanker og/eller erfaringer rundt temaet. Målet er at man kan «løfte blikket» fra egen drift og dele og tilegne seg kunnskap rundt tematikken. Hva fremmer ønsket utvikling og hva hemmer ønsket utvikling i lys av møtets tema.

Eksempler på temaer som drøftes i møtet:

Private utbyggerne	• Hvilke teknologier har dere prøvd/planlegger å prøve i egne prosjekt? • Hva har fungert/ikke fungert etter planen? • Finnes det begrensninger i reguleringsplaner/gjeldende lovverk som vanskeliggjør måloppnåelse? Forslag til løsninger? • Hva bør offentlige aktører gjøre i denne sammenheng? Hvordan bør våre bestillinger utformes for å sikre at klima, miljø og energiambisjoner realiseres?
Offentlige aktørene	• Hva gjøres fra deres side for å nå klimamålsetningene? Hvordan oppleves dialog og samarbeid med private aktører? • Hvilke teknologier satser man på i egne utbyggingsprosjekter? • Hva er behovene til offentlige aktører? Hva ønsker man at private aktører kan levere på?
Teknologi-selskap	• Hvilke teknologier kjenner dere til og kan tilby markedet? (sett i lys av klima-spørsmålet) • Hva er største utfordringen for å tilby energi- og klimavennlige oppvarmingsløsninger? • Hva er største utfordringen i forhold til egenproduksjon av elektrisitet?

Grunnlagsdokumenter

Klima- og energiplan 2019-2031 (vedtatt 9. mai 2019

[1] Prop. 77 L (2016–2017) Lov om klimamål (klimaloven)

Program

08.00 – 08.15 Innledning og presentasjon av møtedeltakere v/Gunvald Johansen Bygg AS og Bodø kommune

08.15 – 08.45 Presentasjon FME ZEN (Hva kreves for et område blir et nullutslippsnabolag, status og Bodøs rolle som pilotområde)

08.45 – 09.45 Presentasjon av aktuelle prosjekt i Bodø

Formålet er å belyse ambisjonsnivået, hvilken teknologier man ønsker å bruke og eventuelle utfordringer man støter på

- Gunvald Johansen: Husbankprosjektet og Sintef-program
- Hundholmen Byutvikling: Ambisjoner for Utviklingsområde Vest (Breivika)
- Avinor: Planer og ambisjoner for ny lufthavn i Bodø
    - Hva er energi- og klimaambisjonen for terminalbygg og bygninger rundt

09.45 – 10.00 Pause

10:00 – 10.50 Innspill og dialog

- Bodø kommune
- Bodø Energi
- Elektro/Nilsson

10.50 – 11.00 Oppsummering

11.00 – 12.00 Lunsj og mingling (frivillig)

Deltakerliste

Avinor

- Helge Albertsen

Bodø Energi AS

- Arne Juell (Konserndirektør Bodø Energi AS)

BE Varme

- Monica Fjellstad (Adm dir)

BE Kraftsalg

- Ole Angellsen (Adm dir)

Nordlandsnett

- Tarjei Benum Solvang (Siv ing Nettutredninger)

Elektro

- Einar Jørgensen (Adm dir)
- Andreas S Melby (Konsernkoordinator)

Nilsson

- Jøran Marthinussen (Adm dir)

Nordkontakt

- Vemund Kristiansen (Prosjektleder IoT)

Hundholmen Byutvikling

- Morten Jakhelln (Adm dir Hundholmen Byutvikling)
- Håvard Engseth (Daglig leder Breivika Utvikling)

Husbanken

- Lena Jørgensen (Avdelingsdirektør)
- Marit Iversen (Seniorrådgiver)
- Arvid Olsen (Seniorrådgiver)

NOBL

- Mona Liss Paulsen (Adm dir)
- Hans Kristian Rabben (Leder NOBL prosjekt)

Gunvald Johansen Bygg AS

- Jørn Vidar Johansen (Daglig leder)
- Eivind Nygård (Prosjektutvikler)

FME ZEN/Sintef

- Judith Thomsen (Forskningsleder)
- John Clauss (Forsker)

Bodø Kommune

- Odd Henriksen (Kommunaldirektør for Næring og utvikling)
- Tove Buschmann-Rise (Kommunaldirektør for Utbygging og eiendom)
- Kai Haakon Kristensen (Utbyggingskontoret)
- Annelise Bolland/Ingrid Nøren (Byplan)
- Rakel Hunstad (Ny by – ny flyplass)
- Marte Melnes (Miljørådgiver)

Mål for møtet

- Treffpunkt/relasjoner
- Oversikt hva som skjer i byen
- Hva har vi ikke kunnskap om?
- Hva kan andre byer/prosjekt lære oss
- Lage grunnlag for flere møtepunkter

Gi tilbakemelding til Eivind Nygård: eny@gj.no om du ønsker lunsj eller ikke.

Jeg kan også nås på tlf: 91114774

Dersom du har praktiske spørsmål så ikke nøl med å ta kontakt.

Vi gleder oss til et interessant og lærerikt møte!

Mvh

Jørn Vidar Johansen Eivind Nygård

Gunvald Johansen BYGG

Husbanken project Gunvald Johansen Bygg AS –

An energy system analysis for Sjøsiden, Bodø

Author: John Clauß, SINTEF Community

Employer: Eivind Nygard, Gunvald Johansen Bygg AS

Abstract

The municipality of Bodø has decided that the current city-airport will be moved further away from the city center by 2026. The planning for the new neighborhood at the current airport area is already ongoing. The ambition of "Ny by – ny flyplass" is a neighborhood where future technological and environmental-friendly solutions will be realized. However, this also means that the new buildings being built before 2026 ideally should use technologies and solutions that make it possible to couple those buildings with the new buildings in the neighborhood "Ny by – ny flyplass".

The work performed in this report is associated to the Sjøsiden project of Gunvald Johansen Bygg AS. The current report focuses on two tasks: (1) identification of building projects, typical technologies and installations to achieve plus energy houses or to reach the zero emission building (ZEB) or zero emission neighborhood (ZEN) ambition. The knowledge gained from previous projects can also be used for the case of Bodø (considering geographical characteristics for infrastructure and climate) to achieve the best results with regards to energy use and greenhouse gas emissions; (2) a pre-study of energy system concepts and a simplified evaluation of the energy use and energy harvesting with the help of simulation tools.

The review on previous building projects on plus energy buildings and ZEBs shows that it is of outmost importance to work towards a defined ZEB ambition level from the planning and design phase already. To achieve a zero emission balance, energy efficiency measures should be applied to a building to decrease the energy demand. Knowing the energy demand of a building, the on-site energy system to generate electricity or heat can be dimensioned to compensate for the imported energy. The literature review on ZEBs shows that a heat pump system is usually chosen as the local heating system, and on-site PV panels are chosen for electricity generation to compensate for energy imported to the building.

An energy system analysis has been performed for three buildings at the Sjøsiden neighborhood in Bodø. The three buildings are a single-family house, a two-family house and a row house. The energy systems considered in the analysis are district heating (DH), combined heat-and-power (CHP) and a seawater heat pump (SWHP). The "reference" system is DH because by regulation there is an obligation to connect to DH if the infrastructure is in place. The performance of the systems is evaluated based on the annual energy use and resulting annual emissions of the buildings. The results show that the SWHP leads to a lower annual energy use for heating and to lower annual carbon emissions compared to the DH system and a CHP plant. The trend is similar for all three houses. The energy use for the CHP plant is higher than the energy use for the DH system because more energy has to be delivered to meet the same demand due to the lower thermal efficiency of the CHP plant. Two scenarios for annual carbon emissions, S1 and S2, are investigated It is shown that the total annual carbon emissions are very dependent on the choice of CO_2 factor. It can be seen in Table 1 that the total emissions for the CHP plant are higher than for the DH system for scenario S1, whereas they are lower compared to the DH system for scenario S2. This difference is due to the choice of emission factors and their respective ratio (S1: 12 vs. 18 gCO_2/kWh for solid biomass and electricity and S2: 50 vs. 132 gCO_2/kWh for solid biomass and electricity). The importance of the exported electricity generated from the CHP plant increases in S2.

Table 1. Annual energy use and emissions for the three investigated energy systems.

Performance indicator	District heating	Biomass CHP plant	Seawater heat pump
***Single-family building** (609 m^2 heated floor area)*			
Energy [kWh/m^2/year]	69	78	21
Emissions S1 [kgCO_2/year]	512	552	234
Emissions S2 [kgCO_2/year]	2183	2005	1714
***Two-family building** (711 m^2 heated floor area)*			
Energy [kWh/m^2/year]	65	75	17
Emissions S1 [kgCO_2/year]	541	606	218
Emissions S2 [kgCO_2/year]	2164	2091	1599
***Row house** (936 m^2 heated floor area)*			
Energy [kWh/m^2/year]	50	57	17
Emissions S1 [kgCO_2/year]	573	615	279
Emissions S2 [kgCO_2/year]	2494	2304	2048

On top of this, a case study is performed investigating different measures to "upgrade" a building from TEK17 to a ZEB-O, where ZEB-O means that the on-site generated electricity compensates for all emissions from the operational (O) phase during the lifetime of the building. Results of the case study are shown for the two-family house. In general, it has been found that the TEK17 building does not reach a zero emission balance for any of the three energy systems. Therefore, the envelope of the building has been improved to passive house standard, the efficiency of the PV panels has been increased from 17 % to 22 %, and the total PV area has been increased to achieve a ZEB. If a SWHP is used, it is almost sufficient to improve the building envelope and the PV efficiency. This is important for a residential area where space for more PV panels is limited. For the DH system or the CHP plant, it is not sufficient to only improve the building envelope and the PV efficiency, but it would also be required to increase the total PV area to generate enough electricity to compensate for the imported electricity (Figure 1).

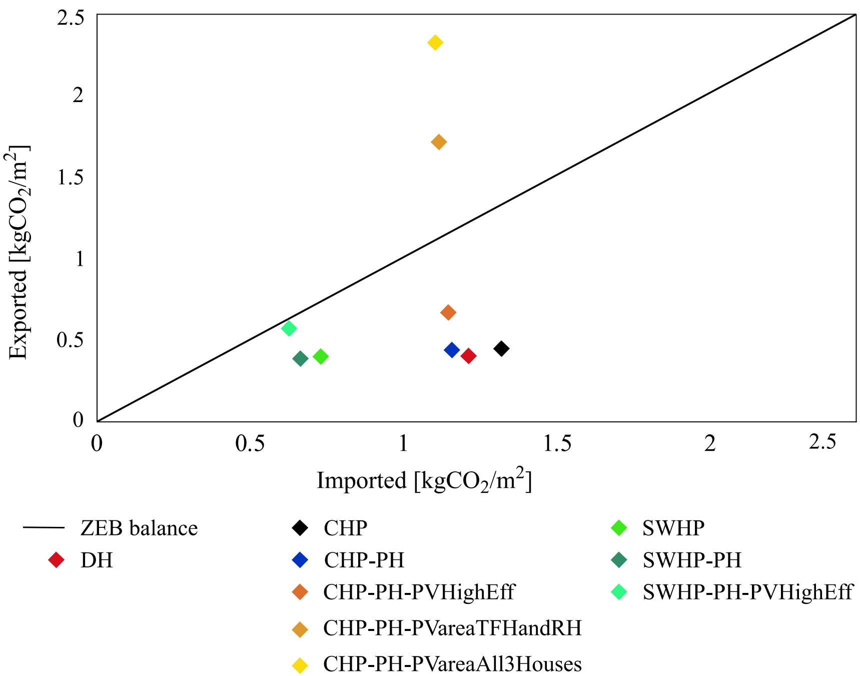


Figure 1. ZEB balance for the two-family house to reach the ZEB-O ambition level.

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1 Background information about ZEB and ZEN

The national strategy "Housing for welfare" aims at realizing purposeful building planning considering the social aspects of housing. Gunvald Johansen Bygg AS is an entrepreneur from Northern Norway and started working in collaboration with Husbanken to achieve the superior goals of "Housing for welfare". In one of Gunvald Johansen Bygg AS projects, Sjøsiden at Bodøsjøveien, they work actively to create a good living environment considering a lifetime perspective. The work performed in this report is associated to the Sjøsiden project of Gunvald Johansen Bygg AS.

The current report focuses on two tasks: (1) identification of building projects, typical technologies and installations to achieve plus energy houses or to reach the ZEB/ZEN ambition; (2) the identification of suitable technologies will be the basis for a specific concept that Gunvald Johansen Bygg AS would like to study. A pre-study of several concepts and a simplified evaluation of the energy use and energy harvesting with the help of simulation tools is performed. The proposed concepts could later be tested within projects at Gunvald Johansens properties.

The main goal of this project is the preparation of a proposal for a pilot project that can contribute to achieving the ambitions of sustainable and comfortable neighborhoods for everyone in "Ny by", Bodø.

1.1 General

This report summarizes findings from a research project called Norwegian Research Centre on Zero Emission Buildings (ZEB). The project lasted for a period of eight years, starting in 2009 aiming at the development of materials and solutions for new and existing buildings with net zero greenhouse gas (GHG) emissions over their lifetime. 21 partners (public and private) from the Norwegian building and construction industry were involved in the ZEB Centre, which was led by the Norwegian University of Science and Technology (NTNU) and SINTEF as research partners. The research project was interdisciplinary so that professionals with different background could work together to solve the questions of how buildings and neighborhoods can help facilitate solutions against climate change. Special focus was given to the following areas of research:

- *General:*
  - Concepts and strategies to achieve zero emission buildings
  - Energy policy, innovations and business models
  - Pilot buildings and neighborhoods
- *Building construction:*
  - Advanced materials
  - Emission-aware energy-efficient building constructions
- *Building operation:*
  - Energy use in buildings
  - Energy systems and technical installations
  - Control of buildings (energy flexible buildings)

Nine zero emission pilot building projects were initiated during the duration of the ZEB Centre. For further information see Andresen et al. [1]. Eight of those projects have been constructed and are in use, while Zero Village Bergen got the permission for starting building construction in September 2019. Zero Village Bergen will therefore become a valuable pilot project in the Norwegian Research Centre on Zero Emission Neighborhoods (ZEN), which is the progression of the ZEB Centre.
The remainder of this Section will briefly introduce the definition of zero emission buildings and the different ambition levels. Section 2 gives an overview of particular pilot buildings of the ZEB Centre and provides lessons-learnt from the ZEB research project.

1.2 Definitions

1.2.1 Zero Energy Buildings

Sartori et al. [2] defined a framework for Net Zero Energy Buildings, also called Net ZEB. *Net ZEB* refers to buildings that are connected to the electricity/heating grid and that are able to do both, consume and generate electricity/heat onsite. *Net* ZEB implicates a balance between the electricity/heat imported from the grid to the building and exported from the building to the grid over a certain time horizon.
When designing a Net ZEB, starting from a reference buildings, the first goal is an improved energy efficiency (Figure 2). This is usually achieved by improving the energy performance of the building envelope, for example by increasing the thermal insulation and by improving the air tightness of the building envelope to decrease the building heating needs. To achieve a Net ZEB balance, local electricity/heat generation (e.g. from photovoltaic panels or solar thermal collectors) is required. Often this ZEB balance is achieved by designing an onsite photovoltaic (PV) system so that it can compensate for the energy use of the building throughout the evaluation horizon.

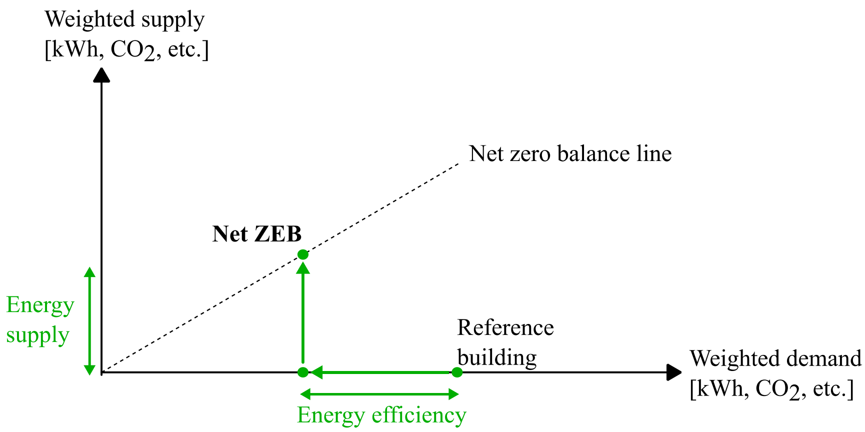

Figure 2. *Concept of Net ZEB balance (adapted from [2]).*

1.2.2 Zero Emission Buildings

The Norwegian ZEB Centre decided to focus on emissions rather than energy and thus, a zero emission building is defined and evaluated based on the calculated GHG emissions during the lifetime of the building (Figure 3) [3]. The GHG emissions are calculated with the help of CO_2 equivalent ($CO_{2eq.}$) conversion factors for each energy carrier ($kgCO_{2eq}/kWh$) and building material ($kgCO_{2eq}/m$, $kgCO_{2eq}/m_2$, $kgCO_{2eq}/m_3$, $kgCO_{2eq}/kg$).

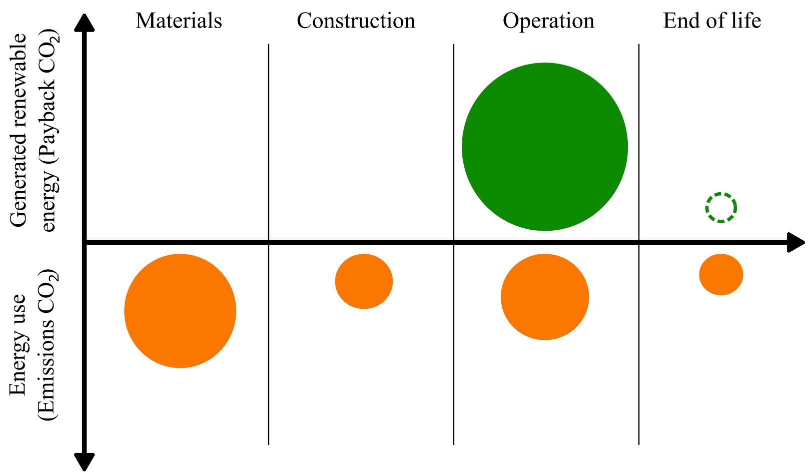

Figure 3*. Schematic view of produced and compensated greenhouse gas emissions during a building life-cycle (adapted from [3]).*

As the ZEB Centre definition is ambitious, a stepwise approach with different ambition levels has been developed to allow for the possibility to consider different stages of the building life-cycle when evaluating the zero emission balance. Figure 4 provides an overview of the different ambition levels defined by Fufa et al. [3]. These levels are briefly described in the following. Emissions are compensated for with renewable energy generation:

- ZEB-O – EQ: Emissions related to the energy use from the operational phase (O), excluding appliances and equipment (EQ)
- ZEB-O: Emissions related to all energy use during operation phase
- ZEB-OM: Emissions related to all operational phase and embodied emissions from materials (M)
- ZEB-COM: Same as ZEB-OM and additionally emissions related to the construction phase (C). The construction phase considers the transport of materials and products to the building site and the construction installation process.

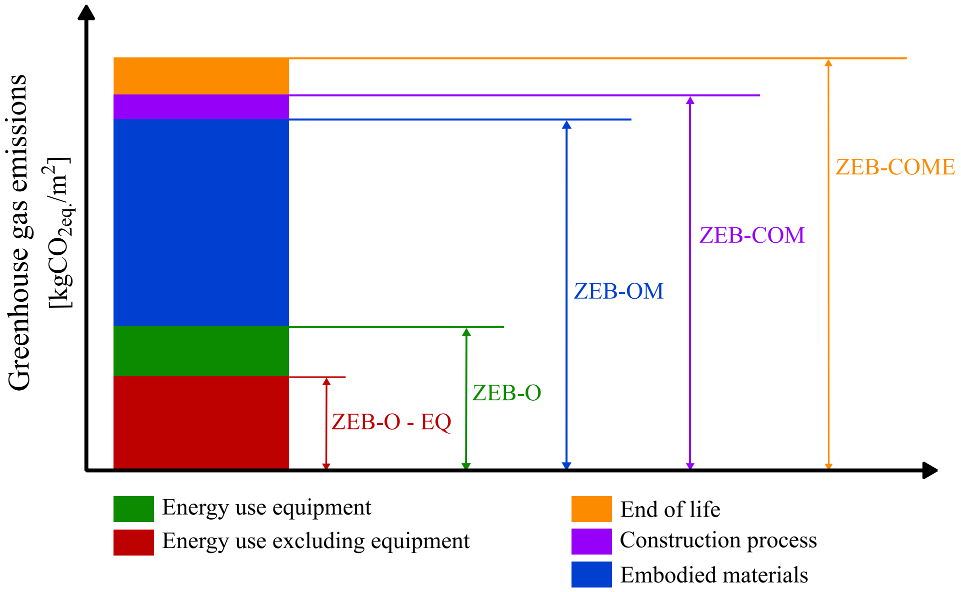

Figure 4. *ZEB ambition levels (explanation in the text above; GHG emissions calculated as kg $CO_{2eq.}$ per m^2 heated floor area per year distributed over a 60 years life time).*

1.2.3 Zero Emission Neighborhoods

A logical progression from a focus on ZEB is the extension to a neighborhood area. The ZEN Centre is aiming at developing neighborhoods that will have a zero-emission balance over their lifetime. The ZEN Centre considers one building as a part of a neighborhood and that buildings can interact with each other to exchange surplus electricity and heat. A first definition for "zero emission neighborhoods" has been developed by the ZEN Centre, but it is pointed out that the development of a comprehensive definition is an ongoing process and a definition will be updated progressively throughout the period of the research project. A tentative, but yet comprehensive definition of ZEN can be found in [4]. An extract of the definition is provided here. A ZEN can be defined as

"[…] a group of interconnected buildings with associated infrastructure, located within a confined geographical area. A zero emission neighborhood aims to reduce its direct and indirect greenhouse gas (GHG) emissions towards zero over the analysis period, in line with a chosen ambition level with respect to which life cycle modules, buildings, and infrastructure elements to include. The neighborhood should focus on the following, where the first five points have direct consequences for energy and emissions:

- *a. Plan, design, and operate buildings and their associated infrastructure components towards minimized life cycle GHG emissions.*

- *b. Become highly energy efficient and powered by a high share of new renewable energy in the neighborhood energy supply system.*
- *c. Manage energy flows (within and between buildings) and exchanges with the surrounding energy system in a flexible way.*
- *d. Promote sustainable transport patterns and smart mobility systems.*
- *e. Plan, design, and operate with respect to economic sustainability, by minimizing total life cycle costs and life cycle system costs.*
- *f. Plan and locate amenities in the neighborhood to provide good spatial qualities and stimulate sustainable behavior.*
- *g. Development of the area is characterized by innovative processes based on new forms of cooperation between the involved partners leading to innovative solutions."*

2 Overview over ZEB projects

The remainder of this Section is divided into two parts:
1) A summary of the lessons-learnt from the ZEB-project
2) An analysis of the 4 chosen pilot projects with focus on materials and technologies that are used to achieve a zero-emission balance

2.1 Summary of lessons-learnt from the ZEB project

In this Section key messages from different ZEB projects and related explanations are briefly outlined. Lessons-learnt from the design, construction and operational phase are presented. This Section is based on a report from Andresen et al. [1], which presents an extended summary of the lessons-learnt.

2.1.1 Design phase

All ZEB pilot projects attempted to use an integrated design process, as described in [5]. This process *"involves establishing clear goals, employing multi-disciplinary cooperation from the early design stages, implementing a high level of energy integration and synergy of systems, and using modern performance prediction tools throughout the process to improve the environmental performance of a building"* [1]. Lessons-learnt are:

1) ***Have a well-defined goal for the environmental ambition.***
   The importance of strong collaboration and involvement of stakeholders, through management style and the establishment of good meeting arenas is emphasized by Moum et al. [6].

2) ***Interdisciplinary collaborations are crucial to achieve the ZEB ambition.***
   Project participants seemed to have an understanding and acceptance of the purpose and need of a ZEB definition. Being involved in the ZEB project gave the possibility of learning and gaining new knowledge to boost personal career and company competitiveness.

3) ***Different design concerns must be viewed as integral parts of the overall concept to achieve a well-functioning ZEB.***
   The focus should be on minimized GHG emissions, high energy performance, quality of indoor and outdoor environments, and architectural qualities. The focus should be on the innovation of the overall concept, whereas the technologies / strategies applied are not necessarily new or innovative.

4) ***ZEB design strategy is based on a passive energy design, which contributes significantly to achieving Zero Emission Buildings.***
   This design strategy can follow a three-step approach to realizing an integrated sustainable energy solution. It consists of the following steps:
   a. ***Reduce energy demand and related GHG emissions by applying energy reducing measures***.
   b. ***Utilize local renewable energy sources***.
   c. ***Use the least polluting back-up solution in the most efficient way***.

   The ZEB Centre developed a more detailed recommendation, which consists of nine measures (Figure 5). The design process should be integrated meaning that interrelations between passive and active measures should be considered when improving/optimizing the concept of a whole building.

5) ***Reduce first! Take measures to reduce the building energy demand as much as possible.***
   This can be done by well-insulated, air-tight building envelopes, passive solar strategies, utilizing daylight, and demand control. The ZEB pilot buildings are designed according to the Norwegian passive house standard ([8], [9]) or better, leading to low U-values for building envelope components.

Figure 5. *Nine measures to consider for a ZEB design.*

Furthermore, strong emphasis should be given to achieving continuous air and moisture barriers in the building envelopes. Cuffs and/or tape can be used to avoid leakages if air and moisture barriers are perforated by ducts or pipes. Skeie et al. [10] point out that for Passive houses, thermal bridges along the basement walls are responsible for a extensive part of the overall heat losses. Therefore, they suggest to insulate these basement walls with 5 cm external insulation.

6) ***Use energy-efficient HVAC systems!***
This helps reducing installation and running costs of HVAC systems. Well-insulated building envelopes leads to lower heating demand and thus heat distribution systems can be designed to be more compact (in ZEB residential buildings, only one radiator per floor, located centrally in the house and near the technical room, allowing for shorter distribution pipes and less technical installations).

Examples of technologies/solutions used in the ZEB pilot projects are:
- Building-integrated PV (BIPV)
- Membrane heat exchanger (Flexit) with heat exchange effectiveness of 90% and decreased need for freeze-prevention
- Façade-integrated solar collectors (NorDan)
- Sliding glass doors with vacuum insulated panels (NorDan)
- Double-skin windows (Sapa)
- Where district heating is available, this is used for auxiliary heating
- Wind power was not selected in any of the projects because of low energy yields due to insufficient wind speeds on site.
- In all except one of the pilot projects (Campus Evenstad), PV systems have been chosen.

7) ***Utilize local renewable thermal energy and electricity!***
Several on-site renewable energy systems are relevant, e.g. heat pump systems, solar thermal collector systems, bio-energy systems, photovoltaic systems or wind power installations. In the ZEB Centre, a common solution was the use of heat pumps in combination with solar thermal and/or PV. Heat pumps can typically be ground-source or sea water-source systems. These systems can be designed to cover 80-100% of the heating and cooling loads. Seven of the ZEB pilot buildings have heat pump systems. Where district heating is available, this is used for auxiliary heating.

8) ***Materials matter!***
The production and replacement of building materials may contribute between 55-85% of total emissions across the Norwegian ZEB pilot projects. Especially for buildings with a minimized

operational energy demand, the relative share of embodied GHG emissions in construction materials and technical installations may be significant. According to [11], [12] low embodied emissions can be achieved by (a) Area and material reduction, (b) Application of reused and recycled materials, (c) Using materials with low embodied carbon, (d) Sourcing local materials and (e) Adopting materials with high durability and a long service life.
Another example can be building integrated ventilation where the layout of the existing building structures is used for ventilation leading to decreased material use for ventilation pipes. Furthermore, nano-insulation materials are an early-stage innovation of the ZEB Centre. These materials are aerogels in combination with concrete and glass. Other product innovations are:

- LECA-stone blocks with integrated insulation materials and mineral wool (lower heat conductivity)
- Use of thermal mass of the building → use of low-carbon concrete
- Mineral wool with reduced conductivity (Glava)

It is pointed out by Wiik et al. [12] that it can be challenging to strictly focus on reducing embodied emissions during a complex project process as decisions on design and material alternatives are based on many criteria (such as technical properties (load bearing capacity, fire safety, durability and sound proofing properties), as well as data availability, cost and time issues).

2.1.2 Construction phase

Especially in building projects with a high degree of innovation and development, good communication between the design team and the executing part on the building site is essential [13].

Positive factors and key for success are:

- "Closeness" between project partners
    - Frequent ***face-to-face communication*** between the central and defining actors in the project team [6]. Increased failures once the distances between actors are increased.
    - *"A problem that appeared was a disbelief shared by the subcontractors when they first became acquainted with the functional demands and the specifications from the design process - a process they knew little about. According to respondents, one important role for a process manager in the later stages could have been to liaise between the project management level (construction manager and contractor) and the subcontractors"* [1].
- ***Contract frameworks***
    - Apply a more ***collaborative framework*** to allow subcontractors to identify and share the risk taking with the main contractors and project owner (Moum et al [6]).
    - A way to ***incentivize sub-contractors to join in more time-consuming contract arrangements*** could be to highlight the skills and knowledge development benefits available for participants in such projects.
    - ***Contract frameworks as source of errors***, as turnkey contract frameworks typically dis-incentivized subcontractors from making order changes, also after they were clearly deemed necessary by consulting engineers [6].
    - ***OBS:*** For solutions to be adjusted and improved directly at the building site:
        - Requires understanding of the intentions behind construction drawings
        - Criterion for success: having enough time to go through challenges and issues with the construction manager and sub-contractors [6].

Costs
Passive houses and ZEBs are more expensive than buildings with lower building requirements. Skeie et al. [10] found that exterior walls and the floor are the two major contributors to a cost increase compared to a building built after TEK10 standard. Costs for exterior walls increase due to a different kind of timber construction to build thicker walls and more work due to increased air tightness and decreased

thermal bridges. They show that the construction of PHs increases costs by approximately 350 NOK/$m^2_{,BRA}$ compared to TEK10. Furthermore, they found that based on their cost evaluation, the additional costs for buildings with an improved energy performance of the building envelope can be rather low, if the most appropriate solutions are chosen. The cost-efficiency varies substantially for different energy systems that consider renewable energy sources. Operational costs savings can be achieved due to a lower heating demand, but the payback time is highly dependent on energy prices.

2.1.3 Operational phase

The residential site Skarpnes in Arendal has been operated long enough to get sufficient data on the energy use of the buildings. Based on the one year of available measurement data, it was found that the measured heating energy use was higher than the predicted energy use. Differences can occur because input data for the simulations was different from the real conditions during operation or because the buildings were not commissioned correctly or not at all.

1) ***Be aware of differences in real weather conditions and simulated weather!***
   Building design is usually performed using a "typical weather year". Real ambient temperatures and solar radiation can differ quite significantly from the "typical weather year" and thus lead to differences in measured and predicted energy use. The local weather also influences the electricity generated from onsite renewable energy sources, which is important for achieving the ZEB balance.

2) ***Don't forget the users!***
   Three key practical/user issues central in ZEBs are identified by Berker [14]:
   1) The level of end-user control
   2) The level of system complexity
   3) The need for information about correct use.

   Users often feel more comfortable with temperatures above 21 °C in common rooms. Furthermore, a rebound-effect could occur, meaning that good standard in buildings leads to increased demands for higher comfort.

   Users want control! (or at least have the feeling that they have)
   1) Users are much less satisfied when they cannot understand how things work or don't have the possibility to control temperatures and ventilation. People are more satisfied when they feel that they are in control of what happens in their homes.
   2) How much control the user gets over his or her environment is much more relevant in a building that is finely tuned to achieve an ambitious overall energy use.

3) ***Information sharing and data visualization is key!***
   Highly energy efficient buildings are usually also more complex than traditional ones which makes it more difficult for users to make informed decisions about the operation. Therefore, it is essential to introduce the house owners and/or occupants into the installed technologies.

2.1.4 Conclusions

Andresen et al. [1] conclude that *"the ZEB definition may advance a Norwegian ZEB standard, where common traits include low-energy, well insulated, timber-framed buildings utilizing passive strategies with high-efficient HVAC systems, and local renewable energy systems. Realizing such buildings does not require new or unknown technologies, but the combination of known strategies, materials and technologies in new and smarter ways. Also, it requires increased investment in time and skills in the early design phases, new contracts for sharing the risk, and more consideration of users."*

Norwegian building regulations that can be of interest for designing ZEB-O buildings are:

- Norwegian technical specification SN/TS 3031 [15] which provides energy performance calculation methodologies
- Norwegian passive house standards NS 3700 [8] and NS 3701 [9] which provide criteria to achieve buildings with low energy demand.

For more ambitious ZEB levels, such as ZEB-OM or ZEB-COM, the following standard can be taken into account:

- Norwegian standard for greenhouse gas calculations of buildings, NS 3720:2018 [16], which is a good starting point for evaluating the effect of material choices.

2.2 Analysis of the four chosen pilot projects

This section gives an overview of previous and ongoing projects on zero emission buildings and zero emission neighborhoods. Here, the main focus is on:

- technologies and materials used to achieve a zero-emission balance over the lifetime of a building,
- costs of zero emission buildings,
- positive and negative experiences from previous building projects.

Four relevant ZEB/ZEN pilot projects are studied in more detail: (1) one single-family residential buildings, *Multikomfort Larvik*, (2) two neighborhoods with several residential buildings, *Skarpnes* in Arendal and *Zero Village Bergen* and (3) the University College Campus, *Campus Evenstad*. Table 2 provides an overview of ZEB/ZEN projects that are analyzed more thoroughly in this report.

Table 2. *Overview of relevant ZEB/ZEN pilot projects.*

	Multikomfort Larvik	**Skarpnes**	**Zero Village Bergen**	**Campus Evenstad**
Location	Larvik	Arendal	Bergen	Evenstad
Building type	Single-family house (SFH)	5 SFH	800 dwellings, terrace houses and blocks	Educational buildings
Total heated floor area (HFA)	200 m^2	700 m^2	80.000 m^2	1100 m^2
ZEB ambition level (design)	ZEB-OM – EQ	ZEB-O	ZEB-O(M)	ZEB-COM

2.2.1 Multikomfort Larvik

Building standard

This single-family house is designed based on the Norwegian passive house standard to achieve a high energy efficiency (see also Figure 2). This building was more of a demonstration case, rather than a cost-effective project.

Materials

The focus on and choice of materials is eminently important for achieve a zero-emission balance for buildings, especially when the ambition goes beyond the ZEB-O level. The choice of materials is a difficult task due to requirements of materials with EPD documentation for an LCA study. In the Multikomfort Larvik, besides wood that was chosen for large parts of the inner wall cladding, bricks were used to increase the thermal mass inside the building. For the ventilation system, a NilAIR system consisting of corrugated plastic pipes with a smooth inner wall surface was chosen over a conventional ventilation tubes (spirorør) which leads to simple distributions systems and easy installation [17]. A general issue raised by one of the project participants is *"that a construction manager with a broader environmental background could [have been] more supportive for the project"* [6].

Technologies
The energy system of the building consists of a heat pump connected to a horizontal ground heat exchanger, solar thermal collectors and a water storage tank. Photovoltaic panels for electricity generation and a battery for electricity storage are installed in the building. In more detail, the ground-source heat pump (Nilan Compact P Geo) has a heating capacity of 3 kW and a COP of 5.17 (both at nominal conditions). The ground heat exchanger is 150 meters long. On top of that, a 100 meter deep borehole can be used as a heat source. The heat pump is designed to cover 80 % of the annual heating demand, whereas solar collectors (16 m^2; Hewalex) cover the other 20 % and are also used for domestic hot water heating. A 400 liter water tank (OSO Hotwater) is used for heat accumulation. The water tank supplies heat to a floor heating system (Uponor) which is installed on the first floor and in the bathroom on the second floor. A water-based radiator (Lyngson) is installed on both floors. A grey-water heat recovery system was considered for the building, where grey-water is taken from the sink, the shower, the dishwasher and the laundry machine and used for pre-heating the water storage tank [17]. In the end, the grey-water heat recovery was not found to be cost-effective and thus was not installed.

Figure 6. *Single-family house Multikomfort Larvik* [18].

Costs
The partners of this project stated that it was difficult to estimate the costs in advance due to the insecurity within the project. The focus of the Multikomfort Larvik project was on knowledge building, not on costs. It was not the aim to sell the house on the market. For this reason, the building was more of a research project than a construction project. Some particular comments regarding costs are provided in [6]:

- Expensive architectural design and outdoor area – mainly due to the indoor staircase, swimming pool, sauna and stone walls in the garden.
- Higher planning costs than usual occurred because architects were involved during the pre-project, and in the follow up of the design process during the construction phase
- Focus on $CO_{2eq.}$ emissions seen as a driving force for higher costs (new solutions are always more expensive and/or time consuming).

2.2.2 Skarpnes

Building standard
Five single-family houses are designed based on the Norwegian passive house standard. Due to technical and cost-related challenges, the construction was changed and adapted during the construction process. In the end, five of the 17 planned houses were built with the zero emission standard, while 12 additional buildings were built with the TEK 10 standard. The focus of the ZEB project was fully on the five passive house buildings [6].

The high insulation level, reduced thermal bridges and the use of concrete in internal walls and ceilings to increase the thermal mass are among the cost-effective solutions installed in these buildings.

Furthermore, an open apartment design allows for natural ventilation. Attention has been paid to a correct orientation of buildings roofs to maximize solar radiation gains [19].

Figure 7. *Single-family houses in Arendal* [6].

Materials
Several "low emission" materials were used for the buildings to reduce the embodied emissions. Among these materials are [19]:

- Mineral wool to improve the insulation capabilities,
- Passive house windows with wooden framing (NordDan),
- Low-carbon concrete to increase the internal thermal mass,
- Wood in construction and as exterior building façade,
- Wood and recycled gypsum boards for the internal facades,
- As well as local stones for the roof.

Technologies
Several advanced technologies have been installed to improve the energy performance and thus to decrease the energy use of the buildings [20]:

- Ground-source heat pump in combination with solar thermal collectors (solar thermal on roof and facades, additional heat fed to the ground in summer; 90m deep borehole for each house),
- Heating system control (home/away control),
- Water-based heating systems (floor heating and radiators),
- Automatically operated exterior sun blinds,
- PV panels for electricity generation on the roof (electricity which cannot be self-consumed is exported to the grid (OBS contract with grid owner (DSO)), important for "el-feeder" dimensioning; total PV capacity 7.36 kW,
- BIPV (32 mono-crystalline silicon PV modules).
- Ventilation with highly-efficient heat recovery (estimated to 86%),

Different possible technical solutions were evaluated by calculations, and some of them, such as solar collector and grey water heat recovery, were excluded during the planning process due to their costs.

Costs
Also in this project, the partners involved concluded that the participation was highly important even though it was financially not profitable, but it was seen as a motor for creation and transfer of knowledge, thus being important for future projects [6].
From the customer point of view, zero emission buildings were more expensive than TEK10 buildings. As an example, the five ZEBs were sold for ca. 4.8 million NOK (154.2 m^2 heated floor area), whereas the twelve other, slightly bigger TEK10 houses were sold for 3.9 to 4.2 million NOK. Excluding the

financial support from ENOVA for the PV panels, the zero emission houses would each have cost 300.000 NOK more than 4.8 million NOK. The zero emission houses were more expensive due to more expensive building materials, technical installations and more required working hours. The hydronic system connected to a ground source heat pump counts for 200.000 to 300.000 NOK; the PV panels account for 140.000 to 160.000 NOK (after 300.000 NOK subtracted ENOVA support), and three-layer windows were also an extra cost factor. In general, two major bottlenecks are (1) the poor introduction of building owners to the technical systems of the house and (2) lacking financial incentives for solar energy systems.

Furthermore, a longer construction phase contributed to higher total costs. The construction of the ZEBs took 1.200 hours, whereas 700 hours were needed to build the TEK10 buildings. The total costs for the construction of the last two houses were reduced by approximately 120 hours due to improvements in the construction process of the walls. According to Skeie et al. [10], the first houses were built with double timber stud walls, which had three times 100 mm insulation. The whole construction process took a long time because the walls had to dry before the vapor barrier and thus the inner wall part could be installed. The inner wall was first build on a provisional inner wall, which later was removed when the third wall layer was ready to be constructed. During this construction process, the wall had to be insulated three times, which all in all lead to a long construction process. A more efficient solution was developed to save construction time and costs. The new timbered wall construction consists of 198 mm thick wall with 50 mm continuous external insulation plate developed by Glava.

2.2.3 Campus Evenstad

Building standard

Campus Evenstad is a University Campus, which consists of 22 buildings and has a total floor area of approximately 10.000 m^2. The campus was also a pilot project of the ZEB-project, where an administration and educational building has been designed to meet the ambition level ZEB-COM. The site is owned and operated by Statsbygg, whereas Høgskolen I Innlandet (HINN) rents and uses the buildings at the Campus [21]. In the remainder of this section, the focus is solely on the ZEB-COM building. The ZEB-COM building consist of the library, administrative and education buildings and includes 31 offices and meeting rooms for academic staff, a reception area, five meeting rooms and classrooms, conference rooms with capacity for 250 people, and a possibility of dividing the space into 2 or 3 smaller rooms and a lobby.

The ZEB-COM building has a total heated floor area (BRA) of 1141 m^2, with an office area of 580 m^2 and an educational area of 225 m^2. A detailed description of the ZEB-COM building at Campus Evenstad is provided by Wiik et al. [22].

Materials

The ZEB-COM building has a solid timber frame construction with wood fiber insulation and a ventilated timber cladding. The timber frame consists of glue laminated timber, solid wood elements and structural timber being joint together by a series of stainless steel plates. Windows are triple-pane. Detailed information on which materials are used in the building and during the construction process is provided by Wiik et al. [22].

Technologies

Most of the heating demand is covered by local energy sources, such as a combined-heat-and-power (CHP) plant (100 kW$_{th}$), solar collectors (100 m^2) and a bio boiler (300 kW$_{th}$). Auxiliary heaters are an electric boiler (315 kW$_{th}$) and direct electric heating. The CHP plant and the bio-boiler are fueled by wood chips and are connected to a local heating grid. The wood chips are produced from a local sustainably-managed forest. The wood chips are transformed into biogas to be burnt in an internal combustion engine. The CHP plant has a power capacity of 40 kW and a heating capacity of 100 kW, with efficiency rates of 20 % and 50 % for the electricity and heat generation respectively.

Water-based radiators with a supply and return temperature of 60 °C and 40 °C are used has the main heat distribution system. On top of that, a wood-burning fireplace provides heat in the entrance area. For the sake of completeness, it is mentioned here that other energy system configurations were evaluated. These did not consider a CHP plant, but rather a higher installed capacity of photovoltaic panels for electricity generation and biomass boilers for heat generation. In the end, the CHP plant was chosen because it achieved the best ZEB balance for the building. To reach this balance and thus the ZEB ambition level, the choice of emission factors for the different materials and technologies used is of outmost importance. Another reason for the choice of the CHP plant is the fact that Campus Evenstad already had PV panels installed at another building that generated electricity during the summer season. Supplementary, the CHP plant can be operated during the heating season, which gives a good match with the existing solar energy system. Advantages and disadvantages of the evaluated energy systems are presented in Table 3.

Table 3. *Evaluation of different possibilities for the energy system of the ZEB-COM* [23].

	Highly-efficient PV cells	Recycled PV cells	CHP plant
Required area	---	-----	+
Risk	+++	+++	-----
Costs	--	-	---(---)
Innovation	-	-	+++++
Possibility for knowledge gain	-	-	+++++
Fit to resources in Evenstad	-	-	+++++

To save energy, demand controlled energy-efficient light emitting diodes (LED) are installed for lighting.

Costs

According to Statsbygg [23] the investment costs for the CHP plant including the extension of the energy substation, the drying of wood chips and the wood storage are estimated to 3.6 million NOK. The total costs are estimated to 5.3 million NOK, also considering the planning, preparation work and a risk addition.

2.2.4 Zero Village Bergen

Zero Village Bergen was a pilot project in the ZEB Centre and is also a pilot case for the ZEN Centre. No buildings have been built because the land-use plan was accepted just recently in September 2019, allowing building construction in some restricted area of the *Zero Village Bergen* area. As no buildings have been constructed yet, limited information is available and thus this section is structured differently compared to the three previous sections.

The first part of this section introduces the questions that were considered during the planning phase of the neighborhood. The second part discusses findings from preliminary studies on the planning of the local energy system. The third part outlines a few social and environmental aspects considered for Zero Village Bergen, thus answering to the third topic of this project focusing on "Housing for welfare".

Considerations during planning phase

When planning a new neighborhood, it is of outmost importance to consider possible energy systems, building designs and area usage during the planning and design phase. The integration of several buildings in a neighborhood opens up new possibilities with regards to energy use and overall energy efficiency due to interactions between buildings. Theoretically, access energy from one building can be used in a neighboring building. It is challenging for a neighborhood to achieve a zero emission balance and system boundaries have to be defined clearly. Some important facts to be considered during the planning phase [24]:

- ***Planning of a neighborhood should be based on a sustainable resource management***
  - Figure 5 can be considered during the planning phase, in this case for a neighborhood
  - Central placement of park areas and spots for local food production
  - Public transport should be placed according to the physical surroundings
  - Use materials with lowest possible carbon footprint (e.g. ZVB plans to have an underground parking house with a timber construction
  - Generation of electricity and heat from on-site renewable energy sources
    - To be used on-site or exported to the grid or near-by consumers
    - Excess electricity can be used for charging electric vehicles or electric bikes
    - Excess heat can be stored in a thermal storage (for long term) or water storage tanks (short-term)

- ***Planning of residential buildings and stepwise neighborhood construction***
  - Typically, buildings should be designed according to the ZEB Centre approach.
    - Building envelopes should meet highest requirements (passive house standard) to achieve low heating demands
    - External window shadings help to keep the indoor temperatures low during summer time, so that the use of an active cooling system is avoided
    - Smart controls for heating, lighting and white goods should be applied
  - Regarding stepwise construction, the aim is to use the increased competence and quality for each new construction area/period
    - An active participation in national and international research projects helps to built competence (IEA Task 51: Solar Energy in Urban Planning; Plus Energy Neighbourhoods H2020 EE-02-2015. Building design for new highly energy performing buildings; Trekonstruksjoner i komplekse nullutslippsboliger – Brann- og fuktsikkerhet)

Discussion on preliminary studies on the local energy system

Similar to a building energy system, the energy system of a neighborhood can be designed based on its energy demand and maximum power use. Preliminary studies on a local energy system for ZVB suggest that it is possible to reach a zero emission balance by considering solar PV and solar thermal collectors in combination with a ground-source heat pump connected to a borehole storage for seasonal heat storage. Another possibility is the use of a CHP plant which runs on biofuels [25]. Sartori et al. found that it was not possible to reach a zero emission balance for ZVB, if district heating was used to cover the heating demand, not even with a CO_2 factor of 0 $kgCO_2/kWh$ [26].

It is pointed out here, that the choice of a CO_2 factor of a respective technology is very important, not only for achieving a zero emission balance, but also for decision-making when it comes to the choice for or against an energy system technology. The Norwegian Standard NS3720:2018 summarizes the $CO_{2eq.}$ factors for several electricity generation technologies. The standard shows that there can be a huge variance in the CO_2 factors for a same technology, and thus the choice for a factor should be made carefully. The ZEB Centre proposed a CO_2 factor for electricity of 132 g/kWh, which is seen an average number for the European electricity mix until 2050. This factor is often used when the emission balance of an electricity-based heating system is determined. To put 132 gCO_2/kWh in perspective, the CO_2 factor of the Norwegian electricity grid nowadays is 18 g/kWh, being significantly lower than 132 g/kWh. This should be kept in mind, when comparing the carbon footprint of different technologies, such as CHP and heat pump systems. CHP plants running on biofuels (wood chips) can have a CO_2 factor of approximately 30 g/kWh, whereas the emission balance of an electricity-driven heat pump is often based on the European average factor of 132 g/kWh, thus leading to a relatively higher carbon footprint even though the current CO_2 factor for electricity in Norway is approximately 18 g/kWh.

Social and environmental aspects for Zero Village Bergen

Among other focus areas, Husbanken supports projects working on the living quality and living environment in a neighborhood. Husbanken defines an appropriate way of construction as *"a quality of the built environment, where physical and social aspects of living, together with the use of resources and energy, a universal design and esthetics, are considered in a holistic form."* ZVB is also aiming towards a good living environment and thus several of the ideas from ZVB can be transferred to projects in other cities. A comprehensive description of the guidelines for ZVB can be found online, [27], whereas some examples are mentioned here:

- Universal design of apartments of different size to make it attractive for as many people as possible to live in ZVB and to stay there permanently (flexible planning solutions for families with children, elderly, people with disabilities)
- Design energy-efficient and environmental-friendly buildings that have a universal design
- Create social meeting places and places for physical activities to promote a welcoming social environment
    - Main square with stores and cafés to have a meeting point for social events, and as the main hub for public transport (see Figure 8 (a))
    - Pedestrian street with restricted traffic (see Figure 8 (b))
    - Car-sharing and bike-sharing spots, where parking spots are equipped with solar cells to allow charging (see Figure 8 (c))
    - Areas for outdoor activities, such as playgrounds, walking paths and kindergarden(s) (see Figure 8 (d))
    - Different neighborhoods to promote variation (see Figure 8 (e))
    - Sharing of goods, such as bikes, kayaks or tools (see Figure 8 (f))

(a) **(b)** **(c)**

(d) **(e)** **(f)**

Figure 8. *Suggestions for a social and environmental-friendly neighborhood based on ZVB* [27].

3 Energy system analysis of Sjøsiden

This analysis aims to provide an input for decision making regarding the application and use of local energy systems for future projects in Bodø, or places with similar boundary conditions.

3.1 Description of the neighborhood

The analysis of the energy system is done for a construction project of Gunvald Johansen in Bodø, Norway. The aim of the analysis is a comparison of different solutions for a local energy system to investigate their performances with regards to energy, costs and greenhouse gas emissions. Here, it should be mentioned that the building construction at the building site has already started and that it has been decided that all buildings have to use district heating (DH). Therefore, it is another aim of this project to investigate whether other energy systems would lead to lower costs, lower energy use or a lower carbon footprint for energy systems other than DH.
The building site is located at the seashore southeast of the city center of Bodø. Three kinds of residential buildings will be constructed in the neighborhood: a single-family house (SFH), a two-family house (TFH) and a row house (RH) with seven units. Simplified building sketches of the buildings are presented in Figure 9.

(a)

(b)

(c)

Figure 9. Simplified sketches of the constructed buildings, (a) single-family house, (b) two-family house, and (c) row house.

3.2 Methodology

3.2.1 Simulation setup

Different energy systems are simulated using the dynamic building simulation software tool IDA ICE Version 4.8. IDA ICE applies equation-based modeling and allows to investigate building energy systems and to evaluate the energy use of buildings. This software tool has been validated in several studies [28], [29]. The energy system analysis, hereafter called ESA, uses the results from the dynamic simulations in IDA ICE as input for a further evaluation of the carbon footprint of the tested systems. Regarding the simulations, the following simplifications and assumptions are taken:

- Local climate data for Bodø taken into account
- Specifications according to Norwegian building regulation TEK17 are considered to achieve a required minimum energy efficiency of the buildings
    - Requirements for minimum U-values of the building envelope and windows
    - Requirements for ventilation as well as internal heat gains from occupants, lighting and electrical appliances
- Schedules for occupancy, lighting and the use of electric appliances based on NS-TS 3031:2014
- IDA ICE provides the possibility to import IFC-files. Starting from IFC-files of the buildings provided by the architects, the information from the IFC files is used to create an IDA ICE model. As the focus is on the energy system analysis and less on the detailed thermal comfort, the room layout is simplified by creating one zone per floor per apartment/housing unit. Assuming that the heating temperature set-point is 21°C in each zone, there are only slight differences in the heating energy use compared to having one zone per room.
- Regarding the SFH: staircase is not modeled as one open room throughout the three levels, but it is included in the zone of each floor level.

3.2.2 Simulation procedure for the energy system analysis

There is one annual simulation for each building and for each energy system. For the sizing of the heating system, a heating load simulation (HLS) on the coldest day is performed for all three buildings. This approach is used to determine the thermal peak load that needs to be covered by the energy system and thus the heat emitting system can be sized for a given design outdoor temperature (DOT), which is -15 °C for Bodø according to [30]. No internal heat gains are considered for this evaluation.
It is mentioned here, that during normal operation of the buildings, the maximum peaks may not coincide due to different occupancy and user behavior, but for the case of HLSs, internal heat gains and user behavior are not considered, thus energy needs of several buildings could be added up to get the maximum possible heating needs.
For the cases of regular annual simulations, interaction of buildings is not considered during the operation meaning that the energy flow between buildings is not considered. In theory, buildings could interact and make use of each others surplus electricity or heat during operation. Several operation strategies can be defined to make full use of on-site generated electricity or surplus heat. For the sake of clarity, different operation strategies are not considered in this report, but are of course worth to be investigated in future work.

3.3 Energy system analysis

The energy system analysis is done on a higher level, meaning that the aim of the project is the evaluation of the energy systems based on the maximum power need and total annual energy demand. Different control strategies for the operation of the energy systems are not evaluated.

3.3.1 Technologies not considered

Several energy systems are not considered in the analysis of this report. These should be investigated in a more extensive energy system analysis. Decisions for or against a system technology are often strategic, based on ambient climate conditions, partners involved in a building project and up for discussion. Due to the limited project capacity, the following energy systems were not considered:

•	Solar thermal collectors	Solar thermal collectors could be used to charge thermal water tanks or supply heat to a local heating grid, especially during summer-time. However, on-site physical space is limited, so that solar thermal collectors are competing with PV panels, BIPV and photovoltaic/thermal collectors (PVT). For this energy system analysis it was chosen to focus on the (so far) most usual system, PV.
•	Ground-source heat pump	A GSHP is a common energy system for Scandinavian residential buildings. It has a high coefficient of performance (COP around 4) and can be coupled to water-based heat distribution systems. The investment costs are rather high, also depending on the ground characteristics, but operational costs are much lower compared to district heating systems or direct electric heating. However, for this project it was chosen to perform an ESA for a seawater heat pump instead of a GSHP system.
•	Air-source heat pump	Initial investment costs for an ASHP are lower than for a SWHP or a GSHP, but an ASHP also has a lower heating capacity and lower performance at lower outdoor temperatures. The advantage of the two other heat pump systems, SWHP and GSHP, is the rather constant and higher heat source temperature throughout the whole year, thus a higher efficiency and lower payback time for the system.
•	Nearby wind turbines	Electricity generation from on-site and/or nearby wind turbines are not considered in this analysis. At least on-site wind turbines are competing with on-site electricity generation from PV, which is much more accepted by inhabitants, mostly because of esthetic reasons.
•	Hydrogen	Hydrogen is not considered in this report because it is not yet a feasible solution for residential buildings.
•	All-electric	An all-electric system (electricity for SH and DHW heating) was out of scope of this evaluation.

3.3.2 Technologies considered

This project focuses on energy systems installed to meet the required heating demand of the three building types. The technologies considered are (1) district heating, (2) a CHP plant and (3) a seawater heat pump. For all three energy systems it is assumed that each building is directly connected to the energy system, but not via a local heating grid.
A heating load simulation (HLS) at the design outdoor temperature of -15 °C is performed for all three buildings. An overview of the resulting heating needs for SH and DHW heating is given in Table 4. The specific characteristics for each energy system are discussed in the remainder of this section.

Table 4. *Thermal capacities resulting from the heat load simulation at DOT -15 °C.*

Characteristics	**Peak thermal capacity**		
Building	SFH	TFH	RH
Peak power / thermal capacity [kW]	16	18	25
Peak power DHW [kW]	8	9	12

All three energy systems can be combined with on-site PV panels for electricity generation, so that it is possible to evaluate whether the buildings could reach a certain ZEB ambition level. The energy systems are evaluated for each building separately.

Photovoltaic panels
PV panels for on-site electricity generation are considered in combination with the three other technologies. With regards to zero emission buildings/neighborhoods, the electricity generation from PV panels is used to compensate for emissions from the building. In this project, it is assumed that PV panels would be installed on the roofs of the three buildings leading to the following total area per

building: (1) SFH, 198 m^2, (2) TFH, 260 m^2 and (3) RH, 310 m^2. The efficiency of the PV panels is set to 17 % which is a typical efficiency of PV panels available on the market. Tilt angles of the panels follow the roof tilt angle.

District heating

District heating supplies heat for DHW heating and space heating. The required temperature for DHW is 55 °C. The energy use from DH considers the delivered energy that is needed to cover the heating demand of the building for both, SH and DHW. Heat losses from the pipes of the DH system are not considered in the analysis. Input data for the simulation of the DH system are presented in Table 5.

Table 5. *Simulation data input for the DH system.*

Characteristics	**Thermal System**	
	Base heating	Peak heating
Simulation input data		
Thermal capacity	Unlimited	Not required
Thermal efficiency [%]	90	-

Combined heat and power (CHP)

A CHP plant typically uses biofuels which can be solid biomass or biogas. Solid biomass has a rather low electric efficiency, but also a rather low CO_2 factor which is advantageous with regards to achieving a ZEB balance. Compared to solid biomass, biogas has a higher electric efficiency, but also a higher CO_2 factor. In this study, the heating efficiency of 69 % and the electricity production efficiency of 11 % is set in accordance with NS/TS3031:2016. The CHP plant is used to supply DHW and SH.

Table 6. *Characteristics of the CHP system.*

Characteristics		**Thermal System**				
		Base heating			Peak heating	
Simulation input data						
Building	SFH	TFH	RH			
Thermal capacity	18	20	25	10	10	15
Efficiency thermal / electric [%]		69 / 11			90	

Seawater heat pump (SWHP)

A modulating SWHP is evaluated as a third alternative. This choice is simply based on the geographical conditions since the Sjøsiden neighborhood is located right at the shoreline. Thermal capacities of the simulated heat pumps are presented in Table 7.

Table 7. *Characteristics of the SWHP system.*

Characteristics		**Thermal System**				
		Base heating			Peak heating	
Simulation input data						
Building	SFH	TFH	RH	SFH	TFH	RH
Thermal capacity	18	20	25	10	10	10
Electric efficiency [%]		Nominal COP 4			100	

3.3.3 System layout considered

All buildings use floor heating as the main heat distribution system in the rooms. In the real buildings, all rooms except for the sleeping rooms have floor heating installed. In this project, this limitation is not considered as one zone per building floor is used instead of one zone per room. A simplified sketch of the heating system layout is presented in Figure 10. The SWHP can be exchanged with DH or the CHP plant for the evaluation of those two energy systems.

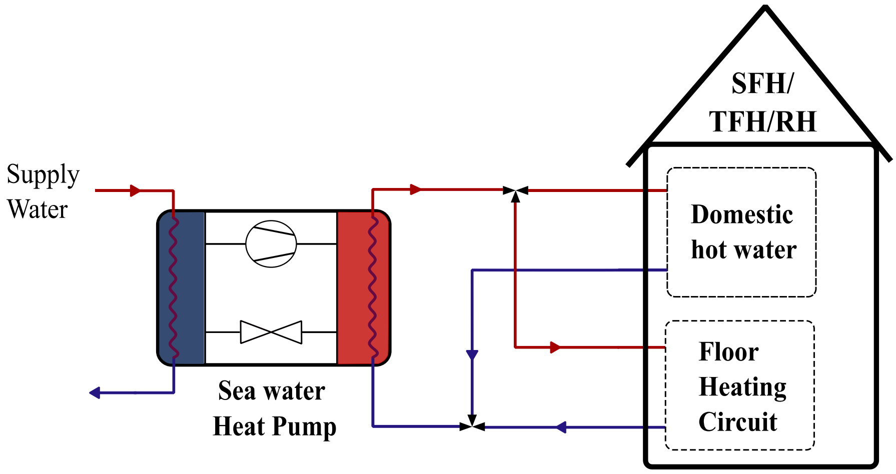

Figure 10. *Simplified sketch of the heating system layout for the case of the seawater heat pump.*

3.3.4 Thoughts on system layouts not considered

Of course, other system layouts could be evaluated, and should be considered in future studies. A non-exhaustive overview is provided in Table 8.

Table 8. *Non-exhaustive overview of possible energy system configurations for the neighborhood (LT-Low temperature, HT-High temperature, LHG-Local heating grid, HX-Heat exchanger, HP-Heat pump; *If both, DH and a LHG are used, they are connected via a heat exchanger in a central substation, e.g. see Risvollan Borettslag, Trondheim as an example).*

Layout	**DH**		**LHG**		**DHW connection to LHG**		**SH connection to LHG**
	LT	HT	LT	HT	HX	HP	
L1*	x		x			x	
L2*		x		x	x		Heat exchanger to connect SH to the (local) heating grid
L3		x			x		
L4	x					x	

Here, exemplary temperature levels for DH and the LHG could be:

- Low-temperature DH (LTDH): 55°C supply and 35°C return
- High-temperature DH (HTDH): 75°C supply and 55°C return
- The supply temperatures in a LHG are always a bit lower than the temperature in the DH grid it is connected to.
- The trend in DH networks is going towards LTDH, as new and renovated buildings have a (much) lower energy demand than old buildings, thus making it unnecessary to supply water for SH at 65°C.
- If LTDH or a low-temperature LHG supplies heat to buildings, then these temperatures may not be sufficient for DHW so that a local booster would need to be installed, e.g. in the form of direct electric heating or a heat pump.

For the cases of a CHP plant and a SWHP, they can be directly connected to a local heating grid, and a heat exchanger in the central substation connected to DH would only be used if the CHP plant or the SWHP was not able to cover the peak heating demands. For that reason, the choices for system design during planning and design phase are important: For example, should the heat pump be slightly oversized to cover peak demands, but run more on/off, which leads to a lower efficiency or should the heat pump be moderately sized so that there might be the risk of having to use DH when it is most expensive?

In the end, the system choice also depends on the private economic and political economic evaluations. Each energy system has different advantages and disadvantages and thus the choice of system depends on the preferences, ambitions, property situation and planned use of the system by the involved partners. Some of the general issues that should to be considered when choosing a system layout are pointed out on the following:

1) Who is owning what in the energy system?
2) Are we interested in energy storage solutions?
    a. One central storage?
    b. Several smaller thermal storages?
3) What does the building regulation say? Are the regulations ready for the evaluated energy system solutions with regards to pricing schemes for the use of de-centralized energy systems (see Askeland et al. [31])?
4) What are we aiming for during building operation?
    - Costs reduction (investment costs, operational costs and/or global costs?)
    - Peak shaving
    - Load shifting

In each design and construction process decisions have to be taken at some point. Therefore, a structured approach that requires good and open communication between the involved actors is necessary in the decision-taking process, so that the evaluation basis is sufficient to take final decisions.

3.4 Comparison

The three energy systems are evaluated based on the annual energy use and annual emissions during building operation (Table 10).

The energy use considers the delivered energy for heating and the delivered electricity for lighting and electrical appliances. Lighting and appliances are included because they impact the total amount of energy to be delivered to the building and the amount of PV electricity that can be used on-site or exported to the grid.

Each electricity or heat generating technology has a specific $CO_{2eq.}$ factor, which is used to determine the total annual emissions and the ZEB balance. As mentioned in Section 2.2.4, the Norwegian ZEB Centre decided to use a $CO_{2eq.}$ factor for electricity of 132 gCO_2/kWh. This is much higher than the current average factor for the Norwegian electricity grid, 18 gCO_2/kWh. Because of the big differences in current and estimated future CO_2 factors for different energy carriers, two scenarios are used in this report (Table 9): (1) $CO_{2eq.}$ factors for the current situation and (2) estimated future $CO_{2eq.}$ factors for electricity and biomass.

Table 9. *CO_2 factors for two different scenarios, S1 and S2.*

Energy carrier	**$CO_{2eq.}$ factor [gCO_2/kWh]**	
	S1: current $CO_{2eq.}$ factor	S2: estimated future $CO_{2eq.}$ factor
Solid biomass	12	50
Electricity	18	132

The results show that the SWHP leads to a lower annual energy use for heating and to lower annual carbon emissions compared to the DH system and a CHP plant. The trend is similar for all three houses. The energy use for the CHP plant is higher than the energy use for the DH system because more energy has to be delivered to meet the same demand due to the lower thermal efficiency of the CHP plant.

Regarding the two scenarios for carbon emissions, S1 and S2, it is shown that the total annual carbon emissions are very dependent on the choice of CO_2 factor. It can be seen in Table 10 that the total emissions for the CHP plant are higher than for the DH system for scenario S1, whereas they are lower compared to the DH system for scenario S2. This difference is due to the choice of emission factors and their respective ratio (S1: 12 vs. 18 and S2: 50 vs. 132). The importance of the exported electricity generated from the CHP plant increases in scenario S2. A detailed overview of the results is presented in Table 11.

Table 10. *Annual energy use and emissions for the three investigated energy systems.*

Performance indicator	District heating	Biomass CHP plant	Seawater heat pump
Single-family building *(609 m^2 heated floor area)*			
Energy [kWh/m^2/year]	69	78	21
Emissions S1 [kgCO_2/year]	512	552	234
Emissions S2 [kgCO_2/year]	2183	2005	1714
Two-family building *(711 m^2 heated floor area)*			
Energy [kWh/m^2/year]	65	75	17
Emissions S1 [kgCO_2/year]	541	606	218
Emissions S2 [kgCO_2/year]	2164	2091	1599
Row house *(936 m^2 heated floor area)*			
Energy [kWh/m^2/year]	50	57	17
Emissions S1 [kgCO_2/year]	573	615	279
Emissions S2 [kgCO_2/year]	2494	2304	2048

A cost analysis has not been performed in this study, but it can be referred to a report by Sartori et al. [26], who have performed an analysis of possible energy system at Zero Village Bergen. They compared DH, a CHP plant and a ground-source heat pump also with regards to global costs of the energy systems and found that the ground-source heat pump leads to the lower global costs even though the investment costs were much higher compared to DH. A similar trend could be expected for the SWHP for the Sjøsiden project.

Table 11. *Detailed overview over annual energy balance and annual emissions.*

		SFH			**TFH**			**RH**		
		DH	CHP	SWHP	DH	CHP	SWHP	DH	CHP	SWHP
DH	[kWh/y]	41330	0	0	47503	0	0	44909	0	0
CHP	[kWh/y]	0	53693	0	0	61690	0	0	58001	0
El_{Import}	[kWh/y]	13771	8443	24228	15459	10035	27591	20882	15756	32435
El_{Export}	[kWh/y]	12886	13591	11247	17059	17662	15478	19000	20272	16919
$El_{Balance}$	**[kWh/y]**	**885**	**-5148**	**12981**	**-1600**	**-7627**	**12113**	**1882**	**-4516**	**15516**
$E_{Balance}$	**[kWh/y]**	**42215**	**48545**	**12981**	**45903**	**54333**	**12113**	**46791**	**53485**	**15516**
EF S1	[kg/kWh]	0.012	0.012	0.018	0.012	0.012	0.018	0.012	0.012	0.018
Em_{S1}	**[kg/y]**	**512**	**552**	**234**	**541**	**606**	**218**	**573**	**615**	**279**
EF S2	[kg/kWh]	0.05	0.05	0.132	0.05	0.05	0.132	0.05	0.05	0.132
Em_{S2}	**[kg/y]**	**2183**	**2005**	**1714**	**2164**	**2091**	**1599**	**2494**	**2304**	**2048**

3.5 Case study on Tek17 to ZEB-O

A case study has been performed to investigate which measures have to be taken to upgrade a TEK17 building to a ZEB-O using the specific case of Sjøsiden and the three buildings from Gunvald Johansen.

The results are presented for the Two-family house and the following measures are investigated in combination with the CHP plant and the SWHP:

- Upgrade insulation level from TEK17 to Passive House (PH – NS3700) until a required U-value is met,
- Increase the efficiency of the PV panels from 17 % to 22%,
- Increase the total area covered by PV panels.

The balance for the DH system lies between the SWHP and the CHP plant.

It is important to know which ZEB ambition level one is aiming for. As a reminder, common procedure to achieve a ZEB balance focuses first on (1) reducing the energy demand of a building and then (2) designing the on-site electricity (or heat) generation based on the energy demand.

Therefore, the first measures to be taken in this case study are the upgrading of the building envelope to PH standard by increasing the insulation level, improving the U-values of windows and doors and by improving the air-tightness of the building envelope. Once the heating needs of the building are reduced, the on-site renewable energy generation technology can be dimensioned. In this case, PV panels are used for electricity generation. To reach the ZEB-O ambition level, the PV panels have to generate enough electricity to compensate for all emissions from the operational phase during the lifetime of the building. Shown graphically in Figure 11, this means that the building has to be above the diagonal line; the further above the line, the more emissions can be compensated for, thus being also able to reach more ambitious ZEB-levels (Figure 4). The analysis in Figure 11 applies the $CO_{2eq.}$ factors for the scenario S1 (biomass: 12 gCO_2/kWh; electricity: 18 gCO_2/kWh).

It is shown in Figure 11, that improving the building envelope from TEK17 to PH standard "moves the building" further towards the left, as the heating needs are decreased and thus less energy has to be delivered to the building to cover those needs. For this specific case study, the insulation thickness of the external walls, the roof and the floor were increased by 12 cm, 10 cm and 4 cm respectively to reach the desired U-value.

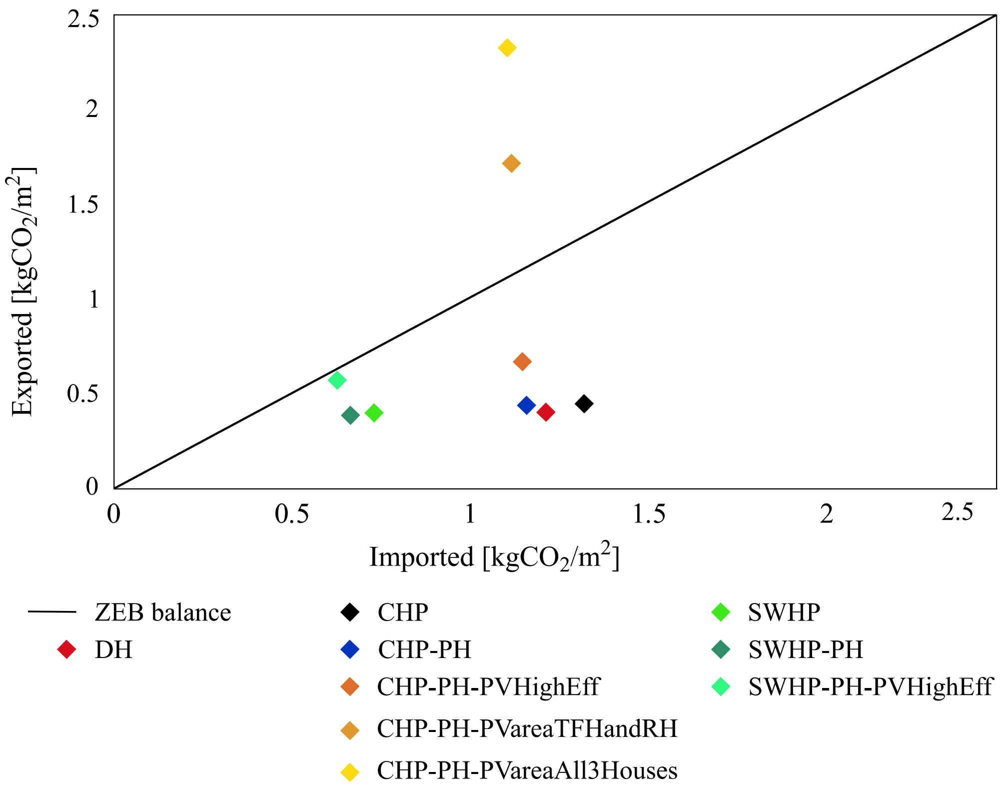

Figure 11. *ZEB balance for the two-family house to reach the ZEB-O ambition level.*

Several conclusions can be drawn from Figure 11:

1. Comparing the three energy systems for the reference building (TEK17) it can be seen that the building is not able to achieve a ZEB-O level for any of the three energy systems. However, the SWHP helps to reduce the imported energy (and thus emissions) significantly compared to DH and CHP.
2. For both, the SWHP and CHP, it helps to improve the building envelope to PH standard to decrease energy imports (*CHP-PH*, *SWHP-PH*).
3. A rather simple measure is the installation of PV panels with a higher efficiency. With continuously decreasing costs and at the same time improving efficiency for PV panels, the application of PV panels with efficiencies around 20 % to 25 % becomes more cost-effective. It is shown that an efficiency improvement from 17 % to 22 % leads to more exported energy/emissions since more energy can be harvested, but not necessarily self-consumed on-site.
    a. It can be seen that the TFH in combination with a SWHP almost achieves a ZEB-O level, if the building envelope would be improved to PH standard and if the PV panel efficiency is increased by 5 %. This is an important finding because it shows that rather simple measures can lead to achieving a ZEB-O level (in combination with a heat pump system). With further improvements in electric efficiency, PV panels get more cost-efficient and, from a practical point of view, this also means that the total PV area does not have to be increased too much to reach the ZEB balance.
    b. Regarding the TFH in combination with a CHP plant, the total PV panel area also has to be increased additionally to an improved building envelope and an increased PV efficiency, to achieve a ZEB-O level. This can be challenging in a residential area where space often is limited.
4. If the measures were taken in combination with the DH system, the effect of the measures on the ZEB balance would be similar to the the effect in combination with the CHP plant.
5. This case study shows that it is important to think about relevant solutions for the energy system already during planning phase, if one is aiming for a zero emission building.

4 Conclusions and prospects on future work

This report focuses on two tasks:

1) the identification of previous building projects and their installed technologies to achieve plus energy houses or zero emission buildings (ZEB). The insights gained are used in task 2,
2) performing an energy system analysis for the specific property of Gunvald Johansen AS, Sjøsiden in Bodø. Three energy systems have been studied for three specific buildings, namely district heating (DH), combined heat-and-power (CHP) and a seawater heat pump (SWHP) for a single-family house (SFH), a two-family house (TFH) and a row house (RH).

The review on previous building projects on plus energy buildings and ZEBs shows that it is of outmost importance to work towards a defined ZEB ambition level from the planning and design phase already. To achieve a zero emission balance, energy efficiency measures should be applied to a building to decrease the energy demand. Knowing the energy demand of a building, the on-site energy system to generate electricity or heat can be dimensioned to compensate for the imported energy. The literature review on ZEBs shows that a heat pump system is usually chosen as the local heating system, and on-site PV panels are chosen for electricity generation to compensate for energy imported to the building. Regarding costs, a heat pump system combined with PV panels has higher investment costs than for example connecting a building to a district heating network, but operational costs are lower for a heat pump system and thus the system amortizes after a couple of years also leading to lower global costs.

With regards to zero emission neighborhoods (ZEN), the presence of ZEBs in a neighborhood is vital to achieve a zero emission balance for the whole neighborhood. Moving from the building-level to the neighborhood-level, system boundaries for the emission balance change. Not all buildings in a neighborhoods need to be ZEBs or plus energy buildings, but some (especially existing) buildings can be "normal" buildings that do not have on-site electricity generation (for example). Regarding the energy system, the integration of buildings into the (existing) infrastructure of the neighborhood is an important point. This is not a trivial task because energy system infrastructure might or might not be in place, and if new local infrastructure has to be installed, the buildings to be connected to the new infrastructure have to be ready for it. For example, if a local heating grid (LHG) is to be used, the energy supply system has to be designed for the temperature levels (supply and return temperatures) of the heating grid and furthermore, the heat distribution systems in the buildings have to fit the temperature level of the LHG. This is one of the reasons, why the planning and design phase becomes more important in the process of establishing zero emission neighborhoods.

An energy system analysis has been performed for three buildings at the Sjøsiden neighborhood in Bodø. The energy systems considered in the analysis are DH, CHP and a SWHP. The "reference" system is DH because by regulation there is an obligation to connect to DH if it the infrastructure is in place. The performance of the systems is evaluated based on the annual energy use and resulting annual emissions of the buildings. On top of this, a case study is performed investigating different measures to "upgrade" a building from TEK17 to a ZEB-O. Results of the case study are shown for the TFH exemplary. It has been found that the TEK17 building does not reach a zero emission balance for any of the three energy systems. Therefore, the envelope of the building has been improved to passive house standard, the efficiency of the PV panels has been increased from 17 % to 22 %, and the total PV area has been increased to achieve a ZEB. Confirming findings from literature review, it is found that the SWHP reaches the zero emission balance easier than DH or a CHP plant. If a SWHP is used, it is almost sufficient to improve the building envelope and the PV efficiency. From a practical point-of-view and based on the ongoing development of PV efficiency, cost-effective PV panels with an even higher efficiency will be available in the (near) future, so that the zero emission balance of the case study building could be achieved by installing highly-efficient PV panels. This is important for a residential area where space for more PV panels is limited. For the DH system or the CHP plant, it is not sufficient to only improve the building envelope and the PV efficiency, but it would also be required to increase the total PV area to generate enough electricity to compensate for the imported electricity.

A few issues and questions that could be investigated in future projects are:

- ***Building operation:***
  - In this project, the energy systems are evaluated for each building separately. With regards to interaction between buildings in a neighborhood, it is recommended to integrate the buildings into one energy system to evaluate the energy use of the buildings combined. This will be important when the focus is on the exchange of surplus electricity between buildings and thus feasible operation strategies.
  - Different operation strategies of the energy systems during operational phase are not considered in this project, but it is important to think about desired goals of operation strategies of the energy systems. More detailed thoughts are summarized in section 3.3.4 of this report.
- ***Regulations, business models and costs:***
  - National or municipality regulations, costs and business models go hand-in-hand as they often influence each other.
  - With regards to the choice of energy systems, what can local entrepreneurs do, if the new buildings are situated in a concession area for DH?
  - With regards to achieving a ZEB or ZEN, was is possible to attribute more public space to PV panels rather than green area? If so, how would that be accepted by inhabitants?
  - How does the local zoning plan consider the businesses of entrepreneurs? For example, if ZEBs are to be built instead of TEK17 buildings, extra insulation in the walls should be installed to decrease building heating needs which leads to thicker walls. If more insulation is put on the inside, living area is decreased and thus sellable living area. Current building are often rather narrow, so that it could not be functional to decrease the apartment width even more. If the insulation is to be put outside, the dimensions of the buildings increases, but the distance between the buildings still has to be kept according to the zoning plan. If many buildings are to be built, it could be necessary to adjust the zoning plan accordingly because otherwise, the increased building dimensions comes at the cost of decreased public area. This problem should ideally be considered during the planning phase already so that architect can take it into account.
  - Regarding costs and business models, who is owning what in the energy system? If a local heating grid is to be built, who is responsible for operating and maintaining it? Who takes the investment costs for a new energy system? If a heat pump supplies heat to a local heating grid, who owns and operates the heat pump? Who owns on-site PV panels, what is the payback time and who gets the possible savings from sold PV electricity?
  - What is the value of the energy systems from a private economic and public economic point of view? If there is an obligation to connect to district heating, is it feasible to built a local heating grid and operate a heat pump to supply heat?
  - Starting from the ZEB definition how can the ZEN definition be adjusted to also consider district heating as a more feasible technology for heat supply. For now, the ZEB balance is purely energy-based and thus favors the technologies that use the least energy to cover the demand.

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