NTNU

Fakultet for arkitektur og billedkunst

Dato12.09.2016 Referanse

Notat

Til:	Gunnar Bovim og Merete Kvidal
Kopi til:	
Fra:	Dekan AB-fakultetet Fredrik Shetelig
Signatur:	FS

Høringsinnspill fra AB-fakultetet på rapport om kvalitetsprogram og overordnet lokalisering av campus i Trondheim

Dekan har hatt ansvaret for utarbeidelsen av begge rapportene og holder seg derfor nøytral i forhold til denne høringsprosessen.

AB-fakultetet har gjennomført høringsprosessen i diskusjonsgrupper på instituttnivå. Fra diskusjonene er det produsert separate innspill fra fagmiljøene. Dette notatet sammenstiller innspillene fra fagmiljøene slik at det kommer frem viktige momenter for den videre prosessen.

Kvalitetsprogrammet:

Det er ikke kommet inn innspill direkte knyttet til kvalitetsprogrammet. Dette må regnes som godkjent av fagmiljøene ved AB-fakultetet.

Rapport om overordnet lokalisering:

Med utgangspunkt i NTNUs strategiske mål – ville mulighet for måloppnåelse øke med en annen lokalisering?

Momenter som taler for en bedre måloppnåelse med en annen lokalisering:

- I stedet for ett sammenhengende campusområde bør NTNUs campus i Trondheim i større grad ses som delområdene Kalvskinnet, Øya, Gløshaugen, Elgeseter og Valgrinda/Sorgenfri bundet sammen av byens gater, bygninger, funksjoner og fremtidsrettede mobilitetsløsninger.

Momenter som taler for at det anbefalte alternativet gir best måloppnåelse:

- Det er riktig å ikke anbefale konsentrert campusutbygging sør for Gløshaugen.

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Er det momenter rapporten ikke berører som kan bidra til å styrke kunnskapsgrunnlaget for en anbefaling?

- Høringsnotatet mangler ideer om NTNUs potensial for integrering i Trondheim som by. Gjennom en kvalitativ vurdering og vekting legges det frem en begrunnelse for et forslag som kan virke forutbestemt.
- De tre alternativene oppfattes som et for begrenset utgangspunkt for lokaliseringsstudien. Alternativene fremstår mer som introverte campus-alternativ i stedet for by-integrerte løsninger. Det vil være mer hensiktsmessig å ta utgangspunkt i de fire eksisterende del-campusene Kalvskinnet, St.Olavs Hospital, Gløshaugen og Valgrinda/Sorgenfri og vurdere hvordan ny bebyggelse kan binde disse sammen. Elgesetergate vil være den sentrale kommunikasjonsåren i campus med mobilitets-knutepunktene Sorgenfri, Hesthagen, Studentersamfundet og Prinsen Kino. Det er ikke problematisert i tilstrekkelig grad at Elgeseter i dag er uegnet som ryggrad i NTNUs campus på grunn av trafikkbelastningen i Trondheims hovedinnfartsåre fra sør. Det er ikke undersøkt alternative mobilitetskonsepter i Alternativ NORD mellom Gløshaugen og Kalvskinnet. Dette spørsmålet vil uansett måtte diskuteres så lenge NTNU også har lokaliseringer andre steder som for eksempel Tyholt.I et 2060 perspektiv vil grønne mobilitets-løsninger sannsynligvis kreve mindre trafikk-areal og dermed åpne for en fortetting langs Elgesetergate.
- Det er ikke gjort vurderinger av potensialet som ligger i å benytte seg av leide arealer i byen. Rapporten utelater med dette et stort fleksibelt areal som allerede er bygget (bærekraftig), bynært (urban kultur) og ikke binder opp universitetet i en for stor eiendomsmasse (fleksibilitet).
- Rapportens «kvantitative analyser» baserer seg på noen forutsetninger som ikke nødvendigvis er holdbare. Analysene definer for eksempel 10 minutters gangavstand mellom bolig og studiested som «lav tilgjengelighet». 10 minutter gir mening som grense for gangtid mellom enkeltstudenters etterfølgende forelesninger men er byplanmessig ubrukbar som maksimumsavstand mellom bolig og studiested.
- Den kvantitative analysen av «potensial for interaksjon mellom Campus og bygninger i byen» er kritikkverdig (side 109). Slik som illustrasjonen nå er tekstet, framstår Gløshaugen som den beliggenhet med «størst potensial for interaksjon med bygninger i sentrum». Dette er objektivt feil; bygninger i sentrum/Midtbyen (og universitetsaktiviteter i disse bygningene) har mye større potensial for interaksjon med andre bygninger i sentrum og med byens liv enn hva bygninger på Gløshaugen har.
- Alternativ NORD scorer lavt på nærhet til partnere for innovasjon. Her tenkes det for avgrenset i forhold til SINTEF og noen få andre. Hva med alle miljøer som er andre plasser i byen? Og hvorfor trekkes det i samme rapport frem aktører som WorkWork, NTNU Accel og DIGS som eksempler på innovasjonsmiljøer? Lignende gjelder areal for ekstern etablering som anses som mangelfull i NORD: Det er mer tilgjengelig areal for etableringer i Midtbyen og østre deler av havna enn på Elgeseter etter at NTNU vil være etablert. F.eks. er ARM med flere lokalisert i byens paradeakse Munkegata.
- Alternativ VEST/NORD scorer likt på synlige og tilgjengelige møteplasser og deling av funksjoner med byens gatenettverk og det må stilles spørsmål ved at en utbygging i høyskoleparken + teknobyen er like integrert i by-veven som Kalvskinnet.
- Lokaliseringsrapporten konkluderer blant annet at «det bør utvikles en park- og bebyggelsesplan for hele vestskråningen mellom Elgeseter og Gløshaugen for å legge grunnlag for konkrete prosjektforslag i området». Å bygge ned en av byens fineste parker vil kunne svekke NTNU som ansvarsfull aktør i framtidsrettet byutvikling. Høyskoleparken har en viktig funksjon som grøntareal i bydelen. En utbygging i vestskråningen svekke den bygningshistoriske verdien av Gløshaugen platået.

Videre prosess:

- Det støttes å gjennomføre en overordnet ide-/arkitektkonkurranse med deltagere og jury på høyeste faglige nivå. Konklusjonene i lokaliseringsrapporten bør kun betraktes som relevant bakgrunnsinformasjon for ide-konkurransen og ikke låse det geografiske området for konkurransen. Alle muligheter for gode lokaliseringer er ikke dokumentert i rapporten. Utbyggingsområdene er i rapporten er i tillegg vist på et abstrakt nivå slik at det ikke godtgjøres at de illustrerte utbyggingsområdene gir gode konkrete løsninger for hverken campus eller Trondheim by.
- NTNUs kompetansemiljø innen bærekraftige byer og bygninger (FME-sentrene ZEB og ZEN, samt Smart & Sustainable Cities gruppen) må involveres i utarbeidelse av konkurranseprogram, juryering og prosjektering. Det må etableres konkrete mål og prosesser for bærekraft i alle faser:
  - Valg av ZEB ambisjonsnivå for både nye og eksisterende bygninger og bruk av ZEB metodikk for beregning av utslippsnivå av drivhusgasser, både på bygningsnivå og på områdenivå.
  - Samarbeide med FME-senteret ZEN om å utvikle nye metoder for å designe bygninger og områder med minimalt karbonfotavtrykk: designmetodikk, analyse- og visualiseringsverktøy og utvikling av definisjoner for nullutslipp på områdenivå.
  - Prinsipper for gjenbruk og maksimalt utbytte av materialers livsløp.
  - Prinsipper for arealeffektivitet og fleksibilitet og pilotering ved testing av nye arbeidsformer og bruk av IKT
  - Samarbeide med Trondheim Kommune om prosesser og metodikk for bærekraftig campus- og byutvikling.
- Byggeprosjektene som nå er i planleggingsfasen, som for eksempel Helsebygget i Elgesetergate 10, må gjennomføres med høye miljøambisjoner. Vi anbefaler sterkt at det planlegges med en ZEB-standard. Dette prosjektet vil sette an forventningene til resten av campusprosjektet. Hele troverdigheten til NTNUs ambisjoner nedfelt i kvalitetsprogrammet svekkes dersom Elgesetergate 10 gjennomføres som «business as usual» med middelmådige ambisjoner.

Ved å ta i bruk vår egen nasjonalt ledende kompetanse kan NTNUs campus flytte kunnskapsfronten og fremstå med best & next practice innen campusutvikling.

Vedlegg:

- Birgit Colds refleksjoner (i dette dokumentet)
- Birgit Colds kronikk om NTNU og Trondheim midtby, mars 2014
- The school of the future – om Heimdal Videregående skole som ZEB-pilotbygg
- School of the future – rapport fra Fraunhofer IRB verlag
- Campus of the future – foresight rapport fra Arup

Kommentar og gode råd fra Birgit Cold, professor emerita, NTNU
20.09.2016

TRE FORESTILLINGER

Tidligere har jeg skissert tre forestillinger om utvikling av NTNU de neste 50 år: SLANGEN: utbygging fra Hovedbygget videre langs høgskolebakken med lameller, ny bro fra St Olav til Midtbyen, kjøpe-leie-bygge lokaler frem mot Leutenhaven og videre til torget som blir NTNU's og Trondheims brukeres felles arena

LANDSBYEN: som bygger ut hele høgskoleplatået som en grønn landsby

MANHATTAN: bygge slanke tårn overalt hvor det er mulig på høgskoleplatået og kultivere parken.

GEOGRAFISK-ARKITEKTONISKE BYDELER

I mine videre refleksjoner over geografisk-arkitektonisk utbygging de neste 50 år vurderer jeg en mulighet for en tydeligere identitet, en slags bydelsidentitet for de aktuelle områdene for utvikling av NTNU.

Tanken om at vi integrerer fag og personer gjennom en fysisk nærhet mener jeg er en illusjon. Styrken i fremtiden (og i dag) er at hvert område: Gløshaugen, Kalvskinnet, St Olav, Elgesetergate fremstår med sin egen identitet og at denne styrkes ved enhver utbygging.

Gløshaugen: oppfattes og forstås som en bydel for teknologi, naturvitenskap, arkitektur, kunst, design, musikk og den innovasjon som hører til disse fagområdene. Parken kultiveres og beplantes slik at det oppstår grønne lunger.

Kalvskinnet: oppfattes som "det nye Dragvoll" hvor også Leutenhaven tas i bruk med samfunnsfag, humaniora, lærerutdanning m.m.

St Olav: oppfattes som medisin, helse og kunnskap innen disse og relaterte områder.

Elgesetergate: kan være en streng med studentboliger, studentrelaterte funksjoner, sport, Studentersamfunnet m.m.

OBS: Fagområder kan naturligvis flyttes, men bydelene består med hver sin identitet.

foresight

Campus of the Future

ARUP

This report is a product of Arup Foresight + Research + Innovation. The Arup F+R+I team identifies and monitors the trends and issues likely to have a significant impact upon the built environment and society at large. We research and raise awareness about the major challenges affecting the built environment and their implications. We help clients think more creatively about the long-term future and manage risk and uncertainty more effectively.

About Arup
Arup is an independent consultancy providing professional services in management, planning, design and engineering. As a global firm we draw on the skills and expertise of nearly 11,000 consultants across a wide range of disciplines. Arup's dedication to exploring innovative strategies and looking beyond the constraints of individual specialisms allows the firm to deliver holistic, multidisciplinary solutions for clients.

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INTRODUCTION

Rather than exploring the future of the physical campus or focusing on a particular institutional typology, this report takes a broader view of the future of higher education as a whole. We have examined diverse drivers shaping the sector's future, predominantly in the UK, and we have assessed the implications that these may have on the future design and delivery of tertiary education. We hope that other geographies will gain something from reading this too, as many of the drivers we touch upon are global.

Over the past two years Arup Foresight + Research + Innovation (FRI) has led a number of conversations and workshop events with higher education institutions and other educational bodies in both the United States and the UK. We have also mentored an MA programme at Central Saint Martins College of Art and Design, London, which focused on developing future scenarios for the higher education sector. We have included their highly imaginative scenarios in the Future Campus Narratives section.

In addition to desk research, we have also had countless conversations with engineers, architects, designers, planners, academics, administrators, facilities managers, technology experts and behavioural psychologists. We are interested in progressing strategic ideas and design concepts about the future of the educational campus, with a view to generating thought leadership which can be shared and codeveloped further.

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EXECUTIVE SUMMARY

What expectations will students have in the future, and how will they want to learn? Over the coming years and decades, the student body will undoubtedly become more diverse as a greater number of mature students enter higher education seeking to develop skills, enhance employment prospects or change career paths. Economic growth in emerging economies will continue to raise income levels over time, leading to an increase in the number of foreign students looking to study abroad. This will intensify the need for higher education institutions (HEIs) in more advanced economies like the UK to cater to varied cultural backgrounds, different learning styles and a broader range of interests.

Meanwhile, a new generation of net-native students will pass through the university system. They will have grown up with smartphones, social media and virtual gaming. They will expect the university experience to reflect the real-time, connected nature of the web. These networked, "always-on" students will want constant access to learning materials and resources, other students, experts and faculty members. They will expect personalised, customizable learning environments. As a result, the future of higher education will be more learner-centred, experiential, immersive and social.

Higher education will also have to become more flexible in order to respond to changing student needs. Busy, mobile lifestyles among older students especially will call for learning solutions that people can easily integrate into their daily lives.

For the most part there will continue to be a need for a blend of the physical and digital campus experience. A purely online service may work for some niche students, for example, foreign students and mature students. But the majority of students seeking higher education in future will want and expect some face-to-face interaction, to build social skills — and to have some fun. Some level of physical interaction will always have a place in higher education.

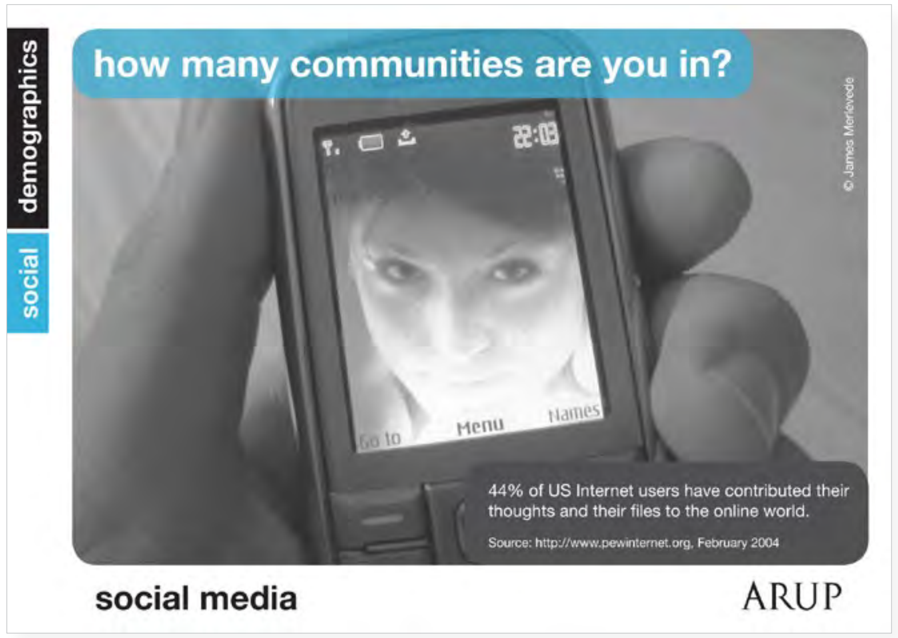
The term *pedagogy* refers to a strategy or style of instruction. For most people today this conjures up an image of a packed lecture hall or a classroom tutorial. However, new technologies are changing the way education is delivered. These developments will mean that entirely new forms of pedagogy will be made possible in the future. These will be radically different from the way that education is delivered today. They may prove to be more effective learning strategies than those employed currently. Multiparty collaboration, peer-to-peer, immersive 3-D or location-based learning are all component parts of a new emergent style of instruction. All of these new forms have been enabled by rapid advances in technology.

These technologies must be embraced fully. Technology needs to drive strategy, and not merely be an add-on. In the words of one of our workshop participants, "If we are not careful the future of education will be more of the same — essentially Victorian, but with more technology".

Drivers of Change

In 2008 as part of an ongoing horizon-scanning programme called Drivers of Change, Arup's F+R+I group identified social media as an issue most likely to change the built environment and society more broadly.

social media
Social media are the online tools and platforms that people use to share opinions, insights, experiences and perspectives with each other. Social media can take many different forms, including text, images, audio and video. Popular platforms include blogs, message boards, podcasts, wikis and vlogs. Facebook, YouTube, Twitter and Bebo are examples of some that have become extremely popular within the last decade.



The future of the higher educational campus will be shaped by a diverse range of complex trends and issues, ranging from social trends such as changes in student demographic patterns to technological developments like the ongoing evolution of social media and virtual reality applications and their integration into higher education. They also include economic drivers such as the globalisation of education markets and increasing fiscal constraints in many regions.

In this report we have identified four thematic areas which we believe will prove instrumental in shaping the future of higher education. They will redefine the notion of the campus in terms of its design, the services it enables and the way in which it operates.

- **Students of the future**
- **Changing the delivery of higher education**
- **Physical facilities and sustainable learning environments**
- **Future skills needed in the marketplace**

1. Students of the future

Tweets

AcademicPub AcademicPub
86% of Young Americans Think College is Essential according to **@CollegeBoard bit.ly/oH4jWw #highered #university**

18-year-olds of the future

In order to better understand the people who will inhabit the campus of the future, we must first appreciate who they will be. What expectations will students going into higher education have in 10 or 20 years from now? How will they want to learn? How will they "consume" tertiary education? What aspirations will they have?

The 18- and 19-year-old students of the future will have grown up in a world dominated by digital technology and communications, mass consumerism and popular entertainment. By the time they enter university they will already have owned an assorted array of PCs, laptops, smartphones, digital cameras and other devices. They will have spent their teen years managing dozens of online profiles, and a plethora of social media sites will have enabled much of their social interaction. It will be absolutely normal for them to be constantly connected to hundreds of friends, colleagues and peers across the world. Their attitudes and behaviours will have been, and will continue to be, shaped by social media, peer reviews, message boards, blogs, Twitter, games, virtual 3-D environments and — of course — popular culture.

HEIs will need to appeal to a tech-savvy Facebook generation for whom working across multiple online platforms and applications, and across a varied mix of media will be second nature. These young students will want higher education environments to reflect the connected, real-time and social context of the web. They will also want educational experiences that integrate the immersive, experiential nature of computer gaming. They will expect online access to colleagues, peers and faculty staff, and they will want instant access to learning materials, data, information and expertise.

Emerging cohorts of students will want to develop the knowledge and skills that can underpin and support a more circuitous, mobile or nomadic career path. On entering the job market they will expect to be equipped with a transferable skill set that will give them greater career flexibility over time. Many of these students anticipate volatile (at best) or adverse (at worst) global economic conditions. They don't expect to find work easily and are ready to compete in a tight job market. To survive, they will need to be agile and opportunistic. They have little faith in public or corporate pension plans and consequently see little obligation to remain with any one employer for more than just a few years. These young people are comfortable with the prospect of moving location to where the job opportunities exist. They may want to actively seek out international experience. These students will be interested in flexible modules, languages and real work experience. They will also want to develop "soft" skills, such as interpersonal and team working skills.

For all students leaving higher education in future, the alumni network will be an asset they will be eager to exploit fully. For a socially networked generation, this network in particular will provide extremely useful contacts throughout an uncertain career future.

"Our students and future students are the 'Net Generation.' They have grown up on video games and the Web, and they expect to be able to transact business and communicate via their mobile phones and other Web-linked devices. This is the number one technology project for the university as we move into enterprise document and content management."

Mike Asoodeh, Chief Information Officer
Southeastern Louisiana University

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Greater diversity

Over the coming years, the student body will undoubtedly become more diverse. This trend will continue as the world's middle classes grow, especially in emerging economies and as further developments in technology and communications unlock still greater mobility and opportunity. There will be more young women entering higher education from all parts of the globe, as traditional mores and customs relax and globalise.

The values and aspirations of the coming generations of students will be further differentiated through personal socioeconomic and cultural filters. In response, HEIs will have to embrace and incorporate processes and structures that help them manage greater diversity and pluralism. They will need to cater to new cultural backgrounds, learning styles and focal interests. Consequently faculty profiles, curricula and teaching approaches are likely to change to reflect the demographic shift within an increasingly hyperdiverse student body.

Universities in the UK and North America will continue to be the preeminent destinations for quality education for many students, most notably from emerging economies. This will continue even as higher educational standards in their domestic markets improve. Young people will look to improve their English, which will remain the world's preeminent lingua franca, for the next generation at least. Many of these students will also look to have an enriching cultural experience abroad while they are young.

Language will become a significant challenge facing HEIs in the future. In response many universities will offer more bespoke services to visiting students to ensure that they are getting the support they need to navigate the university system and to develop their spoken and written language effectively.

Mature students

HEIs will see a greater number of mature students enrol as more countries experience ageing populations. This global phenomenon is putting pressure on people of working age (typically 16 to 64 years old), as their dependents grow in number (ie, children under the age of 16 and the elderly). In the UK, the age at which the British worker will retire will continue to rise over the coming decades. The government has recently published new proposals to increase the state pension age to 66. A pensionable age of 70 or 72 may not be uncommon in 20 or 30 years from now.

Adult education learning will play an important role for ageing workforces everywhere as individuals seek to enhance career and personal development, or to switch careers altogether. An older working population will also need to adapt their skill sets as workplace and employer requirements change over their longer working lives.

As lifelong learning scales up, the age differential among students will increase. This will generate yet more diversity among the student body and will raise new challenges for HEIs. Mature students will have different expectations than younger students with regards to the skills and knowledge they would like to acquire, focusing primarily on those that help advance career prospects. They will likely be more interested in vocational and technical training in order to develop career-specific skill sets.

They will also want to acquire further education in different ways. Most mature students have extremely busy lifestyles, managing family and other commitments on a daily basis. These students will seek solutions that they can easily integrate into their schedules. They will want greater choice and flexibility, and they will expect secure, remote access to the information they need when they need it.

© Parker Michael Knight (Flickr)

"A lot of UK universities either don't offer online courses or, if they do, treat them as an afterthought. We put our online programme on the front page of our website. We see it as integral to our future."

Julie Stone, Head of Online Learning University of Derby

University of Derby

The University of Derby has over 1,500 online students paying between £8,000 and £9,500 for BA and BSc courses such as psychology, IT, accounting, finance or international hospitality management. According to the university, students are typically in their 30s and 40s, and are studying part-time while also holding down full-time jobs. Two-thirds of their students come from overseas.

2. Changing the delivery of higher education

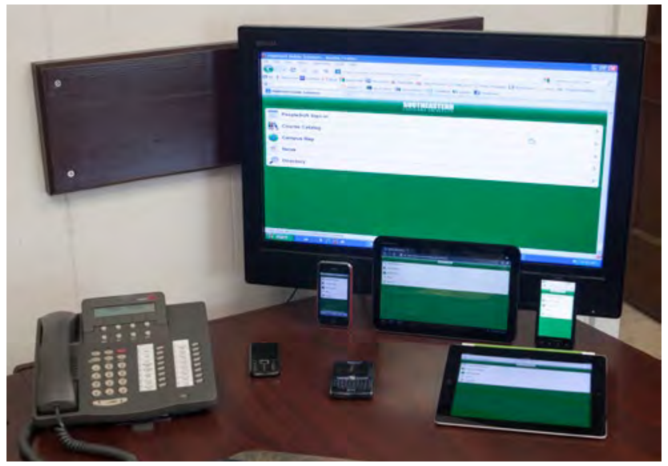
Two million US students are currently enrolled in virtual education programs. By 2014, four million students are expected to receive their degree through online-only education — an increase of 44% since 2009.

Technology-enabled

The internet has already brought about an abundance of novel digital and remote learning platforms. However, further advances in information and communications technology (ICT) are leading to the creation of a range of entirely new learning platforms, spaces and environments. This has been driven in part by the rise in demand for greater flexibility and by the need for providers of education to reduce costs.

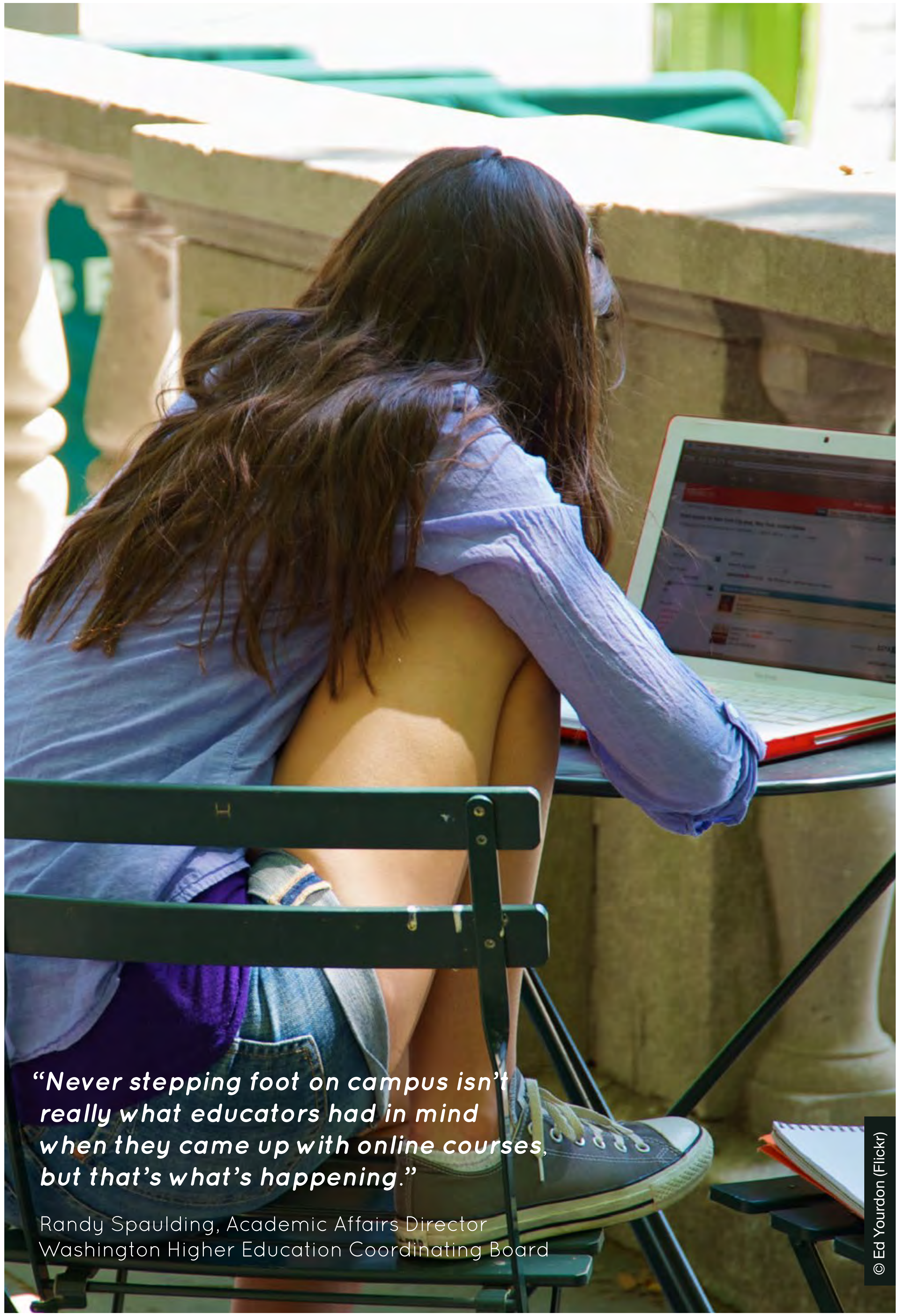
These technologies will enable new ways to integrate learning into the workplace, community and home. These web-based solutions will enable remote access to learning materials across multiple platforms. The benefits of this kind of remote education are particularly evident for students in world regions where there is limited access to affordable, quality higher education. This will also be practical for those students who have children or who cannot commit to full-time university education.

ICT will play an even bigger role in the design of new physical learning spaces and environments. Learning tools based on social media applications, 3-D virtual environments and real-time multiparty collaboration will transform the way educators deliver educational experiences to students, fundamentally rewriting the way a student's needs are addressed.



Southeastern Louisiana University

The Total Mobile Access programme at Southeastern Louisiana University allows students to access the status of their financial loans, grades, course details, class schedules and individual planners online from different devices. Faculty members can also look up student information, review teaching schedules and access individual student grades.



"Never stepping foot on campus isn't really what educators had in mind when they came up with online courses, but that's what's happening."

Randy Spaulding, Academic Affairs Director
Washington Higher Education Coordinating Board

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Connected

The ongoing ICT revolution will lead to ever more pervasive connectivity. We will witness unprecedented levels of personal connectedness as new models of smartphones and tablets come to market, and as the speed and bandwidth of mobile internet access increases.

Academic performance will be greatly enhanced by real-time access to quality information. For example, web-based technology will enhance lectures by providing high-quality teaching tools and course materials. This will create new opportunities to engage students, deliver the latest content, monitor student participation and assess individual performance.

As we look even further out towards 2030, trends like wearable computing will penetrate mainstream education, with unique and novel applications for students. Embedded access to information will make it easier for students to get up-to-date knowledge and information.

UCSI University Maxis-Sponsored Wi-Fi

UCSI University is a leading Malaysian institution of higher learning with campuses in Kuala Lumpur, Terengganu and Sarawak. The university has recently signed an agreement with Maxis, Malaysia's leading integrated communications service provider, to provide high-speed internet to the university and become one of the university's industrial partners. The service will enable students to interact with their lecturers outside the normal class setting, combining the usual face-to-face learning with online delivery methods. High internet speeds will enable students to quickly download podcasts of their lectures, access online resources, conduct research and join online group discussions.

University of Southern Denmark

A Danish university has adopted an unusual strategy to tackle cheating: allowing unfettered internet access, even during examinations.

Lise Petersen, e-learning project coordinator at the University of Southern Denmark, explains that all handwritten exams are being revised and transferred to a digital platform wherever possible, with a completion date of early 2012. She found that the use of online assessment opened up the prospect of creating tests that could be automatically marked and graded, saving academics time.

Flexible

As we head towards a future characterised by hyperdiversity, HEIs will have to respond by scaling up customized learning solutions and by offering flexible products and modular services that cater to diverse student needs. Solutions include part-time learning and entirely online-based services.

HEIs must create learning environments that help a wider range of students from across a broad range of cultural backgrounds achieve individual educational goals. Students will seek personalised, customizable learning environments and schedules.

Resource-rich

The internet will provide access to a fast-growing resource pool of quality teaching materials and online lectures. Many of these resources are already being provided by some of the best universities in the world. For example, MIT OpenCourseWare offers free online access to all course materials to anyone. This trend will continue to threaten the monopoly that established providers have historically held in supplying the higher education market.

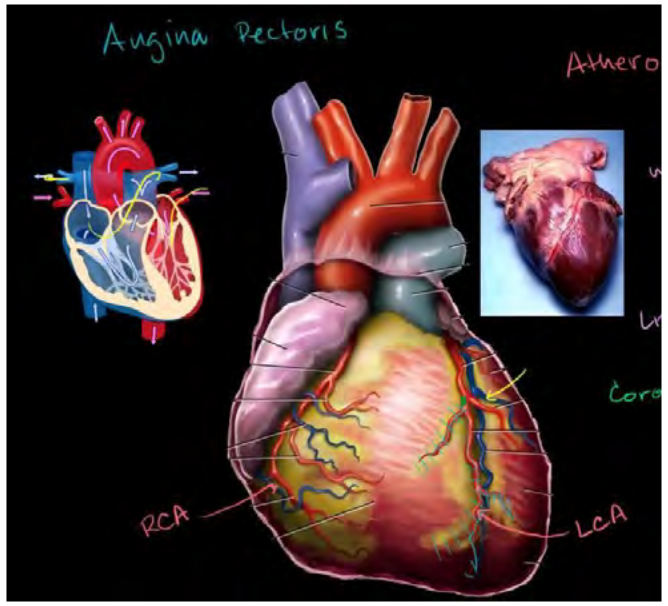
Kaplan University

An example of a university that offers flexible learning modules for people with busy lifestyles is Kaplan University, based in the United States. Here students can chose exactly where and when to study.

"At Kaplan we understand non-traditional students — working parents, late bloomers, career changers — have obligations beyond school. As a university that's student driven for driven students, you'll attend classes in a flexible learning environment with schedules designed to fit your life. With the freedom to take classes on campus, or online, on your terms, you can meet academic requirements without sacrificing personal or professional duties."

Walden University iTunes U

Walden University has expanded MobileLearn with its new site on Apple's iTunes U, where an exclusive community of colleges and universities from around the world shares its content for free. First launched in 2009, MobileLearn gives Walden students the flexibility to decide where and when they learn, and choose how they learn to match their preferred learning style. Visitors to Walden's new iTunes U site can find course content and experiential videos, plus highlights of the achievements of Walden students, faculty and graduates, and other resources. This is all available for download in the same way that individuals access music and movies using iTunes.



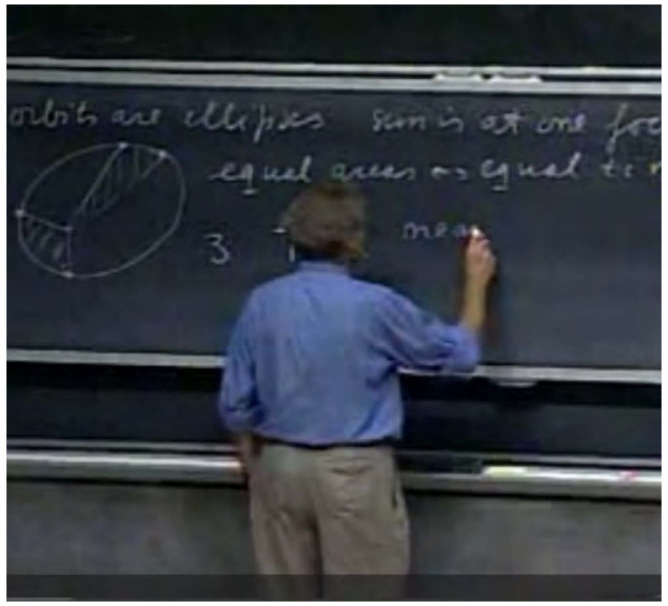
The Khan Academy

The Khan Academy is “an organization on a mission”. It’s a not-for-profit with the goal of changing education for the better by providing a free world-class education to anyone anywhere. All of the site’s resources are available to anyone, and they are completely free of charge. As their website explains:

> *“We’re full of game mechanics. As soon as you login, you’ll start earning badges and points for learning. The more you challenge yourself, the more bragging rights you’ll get.”*

United Nations University of the People

University of the People (UoPeople) is “the world’s first tuition-free online academic institution dedicated to the global advancement and democratization of higher education.” Its high-quality, low-cost global educational model embraces the worldwide presence of the internet and lower technology costs to bring university-level studies within reach of millions of people across the world. With the support of respected academics, humanitarians and other visionaries, the UoPeople student body represents a new wave in global education.



Academic Earth

New York–based Academic Earth aims to make a world-class education available to everyone on the planet. Toward that end, it is building a user-friendly ecosystem that gives internet users around the globe the ability to find, interact with and learn from full video courses and lectures from the world’s leading scholars. More than 1,500 video lectures are currently available on the site, covering economics, entrepreneurship, history, law, medicine, religion and the sciences, among many other topics.

Collaborative

Much of the virtual infrastructure currently in use or under development focuses on the enabling of social interaction and networking. This trend will further fuel collective learning among students from all over the world. As these platforms advance, they will complement or supersede classroom-based discussions. An example of this is Classroom Salon, a social networking application designed to offer online learning communities, where students can collaboratively study and work on those topics of most interest.

New educational models and approaches will be required to help multiple generations and cultures learn with and from each other. Cross-departmental and interdisciplinary learning, collaborative peer-to-peer learning and student mentorship will become increasingly common, driven also by the need to cut costs.

Collaborative learning will change relationships among students as well as between the teaching faculty and the student body. For example, teachers may find that they learn more from the students than they have in the past. Students may be better positioned than faculty to pick up on new developments in spheres such as ICT and its impacts on sociocultural norms and behaviours, much of which may be to a greater degree driven by younger generations. International students will offer a window into other cultures and cultural perceptions that teachers may have not had first-hand access to in the past.

Moodle

Moodle (Modular Object-Oriented Dynamic Learning Environment) is an example of a virtual learning tool empowering lecturers and students alike. The Moodle platform enables the open-source development of learning tools and has more than 41 million users in 213 countries. Many of these new online education platforms are built around the concept of peer-to-peer teaching, where one student provides content or teaching to another.

Experiential

Immersive and experiential learning environments will become more common over time. These contextual or location-based learning spaces can take many different forms. For example, pop-up learning labs may take over disused spaces in suitable locations that relate to a specific focal area of study. They are fitted out with light, heat and power, and students have access to Wi-Fi. These transient, networked learning spaces are temporary and low-cost, and offer students an experience that they would otherwise not have. An example of this is HafenCity University Hamburg's University of Neighbourhoods, which offered summer school students studying architecture and urban planning room and board in a disadvantaged neighbourhood.

As display technologies and virtual 2-D and 3-D environments improve, so will the ability to create effective, experiential virtual learning laboratories. Ambient intelligence will augment learning labs and spaces, and gaming components will help engage students. This will give students the chance to have realistic, immersive experiences that would otherwise be beyond their reach.

We can expect to see a rapid development in augmented reality and other virtual tools and technologies that offer new types of learning experiences, both online and offline.

In the longer-term, online-based learning environments may be fully immersive, where content is delivered through avatars or through a set of interactive and iterative learning journeys in 3-D. Robots or other forms of artificial intelligence might even take over teaching roles.

"A learning environment might look like a giant replica of a human heart which medical students can explore at a previously unattainable level of depth and scope, or it can look like a fuel cell, magnified a thousand-fold to allow learners to witness scientific processes in action."

creatingthefuturetoday.com

virtual gaming

Jupiter Research estimates that the massively multiplayer online games (MMOGs) industry generates revenues of US$350bn a year and occupies about nine hours a week for the typical player. Most gamers are between the ages of 18 and 34. MMOGs fall into four genres: fantasy, sci-fi and superhero, combat simulation and first-person shooter, and social and other situation-based games. Fantasy games hold the highest market share. A Forrester consumer report says 21% of North American consumers regularly spend leisure time playing games, with the MMOG category taking up a significant portion of that number.

The younger the adult, the more likely they are to play consumer or video games online. Online gamers are also more likely to be "hardcore" gamers: 42% say they spend at least four hours playing games during an average week. The popular MMOG Second Life makes about US$5.3m in user transactions over the course of one month, and its membership has been growing by 20% a month.

The University of Neighbourhoods (UdN)

The UdN was a research and education initiative created by HafenCity University Hamburg in cooperation with the International Building Exhibition in Hamburg, Germany. The project took place in a former health centre in the heart of the Wilhelmsburg district on the Elbe Island, not far from downtown Hamburg. The building was set to be demolished in 2016. In the meantime, it was fully fitted out as a temporary study space where up to 20 international students spent three weeks each summer. During this time they developed urban design projects for the surrounding community, exploring themes such as urban regeneration, gentrification and immigration and sustainability. By living in the neighbourhood they got an immersive experience based upon active participation and real engagement with community and stakeholder groups living and working in the area.

ShanghAI Lectures

The ShanghAI Lectures project is a virtual collaborative environment that aims at:

- exploring novel methods of knowledge transfer
- overcoming the complexity of a multicultural and interdisciplinary learning context
- making education and knowledge on cutting-edge scientific topics accessible to everyone
- bringing global teaching to a new level

The ShanghAI Lectures, which focus on natural and artificial intelligence, are held via videoconference at the University of Zurich in Switzerland, the University of Salford/MediaCityUK in the United Kingdom, and Shanghai Jiao Tong University in China, in addition to 12 other universities around the globe. Students from these participating universities work together on exercises, using a powerful robotics simulator software. This is complemented by 3-D collaborative virtual environments and other community-building activities to promote interaction and cooperation among the participants.

3. Physical facilities and sustainable learning environments

University of Chicago
Joe and Rika Mansueto Library

The Joe and Rika Mansueto Library has been designed to accommodate online study and research. The structure's large spaces are made for computer work and have no traditional bookshelves. Instead, the library boasts a massive underground storage area holding 3.5 million volumes on 50-foot-high shelves. A robotic retrieval system finds books and other materials on request. So "students and scholars can scour the web for hours for academic papers and still get a hard-to-find volume from the stacks."

Virtual campus environments have existed for some time and will undoubtedly grow in numbers as the century progresses. However, one cannot disregard the advantages that a physical campus can bring in terms of access to facilities, research equipment and other resources. Nor should one overlook the basic human need for physical social interaction. Chance encounters, serendipitous conversation and recreational activity all play a fundamental role in any one person's education and life journey. These encounters provide a deep level of sensory engagement and lead to the development of important social bonds and friendships, interpersonal skills and memory creation. In short, the physical interface cannot be replaced entirely by technology.

To compete with virtual spaces, online platforms and web-based environments, physical learning environments will have to provide benefits that go beyond face-to-face access to people. They will have to be places where students genuinely want to spend time. Compelling reasons might include access to specialised facilities such as "smart" classrooms and lecture theatres, or access to high-quality, healthy food at affordable prices.

So what will the future of the physical campus look like? ICT will become more embedded in the physical infrastructure and building envelope, driven in part by the need to improve operational efficiencies and cut costs. This will create a layered digital and online landscape with which students, faculty and staff will all interface.

The relationship between virtual and physical will shift and change over time, and it will be unique to each HEI. An example of this blended, synergistic relationship between the physical and virtual is the new library for the University of Chicago. It offers a fully automated underground storage system for books, articles and periodicals. This has freed up space for an open, uncluttered learning environment above ground without compromising the students' need for access to material resources.

In the future, campuses will evolve into a dynamic, enmeshed network of physical and virtual facilities, where students have a choice in using those facilities that best fit their individual learning styles. Creating and interlinking networks between both physical and digital components will become more important as users seamlessly switch from one mode or platform to another.

intelligent buildings

According to the Intelligent Building Group, "An intelligent building provides a sustainable, responsive, effective and supportive environment within which individuals and organisations can achieve their objectives." Intelligent buildings can be high-tech or low-tech. For example, high-tech buildings embrace the Internet of Things, allowing hardware to communicate to each other and to users. Modular construction, on the other hand, can provide low-cost, low-tech housing suited to the environment.

These pressures will reshape how universities are designed and built, and how university facilities function operationally. Issues such as energy consumption and carbon emissions will become more important as universities and colleges try to attract students using improved sustainability credentials, policies and practices.

Greener methods of education delivery will emerge over time. For example, we may see HEIs purposefully constraining the need for education-related mobility and resource consumption by promoting cycling and walking, remote working and telepresence solutions, or by providing local learning hubs and coworking spaces rather than one large centralised campus.

University of Graz

Some 85% of students at the University of Graz get to class each day using transportation other than automobile, and electric bikes are a popular choice. In fact, e-bikes are reportedly expected to increase in number in Austria from 2,750 to 400,000 over the next 10 years. With just such eco-minded commuters in mind, Energie Graz launched its new locker-equipped power station. Now any of the university's 27,000 students and 3,500 employees can charge up their e-bikes on campus while they work or attend class, with protection to keep their batteries safe. The university also has regular charging stations that can be used without removing a bike's battery.

University of Canberra: Bottled-Water-Free Campus

With its decision to ban the sale of bottled water, the University of Canberra has become the first Australian institution to have a bottled-water-free campus. The move, first initiated by the environment action group Do Something! and supported by students and university authorities, will potentially eradicate over 140,000 single-use bottles of commercially manufactured water.

EcoCampus Award Scheme

The UK national EcoCampus scheme for higher education raises awareness and increases competition among HEIs to be more sustainable. EcoCampus provides support in the management of key areas of environmental impact, in particular tackling climate change and helping HEIs to manage the carbon reduction target and strategy for the higher education sector. Universities will need to turn challenging sector goals in carbon reduction into institutional objectives and targets, and then track performance in an environmental management programme. EcoCampus can help them do this, improving their carbon footprint and environmental progress in logical steps.

EcoCampus offers a flexible approach, with recognition of progress through four awards:

- Planning (Bronze)
- Implementing (Silver)
- Operating (Gold)
- Checking and Correcting (Platinum)

Physical campus spaces will become more flexible in the future, to allow facilities managers to respond more rapidly to student and faculty needs and demands. Asset optimization, a buzzword in the business of estate management, looks to ensure that every square metre of space is used as fully as possible. This will continue to drive strategy and planning.

Campus buildings and spaces are likely to take on multiple functionalities. For example, during holiday periods a space may take on an entirely different role. A courtyard might turn into a festival, exhibition or retail venue, or a lecture theatre may become a cinema open to the public. This is happening already to some extent, but it will become much more common in a cost- and resource-constrained future.

In addition to their obvious financial benefits, public engagement events can also improve the integration of HEIs and their student bodies into the wider community. Campus facilities could become the centre of their community in future, offering sports, entertainment and shopping to students and the public alike.

Over the years security, personal safety and wellbeing will become increasingly important to students as factors in choosing a university. Crime rates typically rise during prolonged periods of economic stagnation or depression. In the context of what may prove to be an extended period of flat or negative economic growth, at least in many developed countries, we can expect to see increased cybercrime, identity theft and other criminal activity. HEIs will need to ensure that they can create attractive and safe physical campus environments for students and faculty staff, especially those in city centres or with a significant online footprint.

Tweets

NumberCloak Number Cloak
Who's going to **#university** this year? Be safe not sorry when handing out ur phone number see how @ **numbercloak.com** **numbercloak.com/blog/genral/fr...**

karynclimans karyn climans
@marcyberg all we can hope for is they're happy and safe **#kids** **#university**

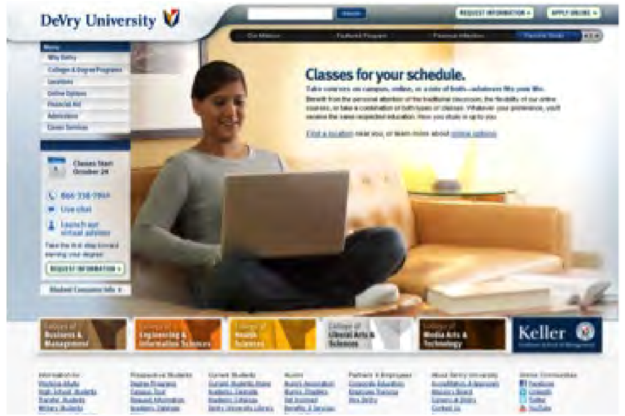
BikeShepherd Bike Shepherd
#US College students have a 59% chance of their bike being stolen during 4 year term on **#campus**: Reg & tag your **#bike** at **bikeshepherd.org**

4. Future skills needed in the marketplace

Industry requirements

The shape of HEIs and their campus environments will be in part decided by the future shape of the economy. While this is extremely hard to predict, we can be sure about certain economic, industry and business trends that will influence the way HEIs organise and deliver educational services.

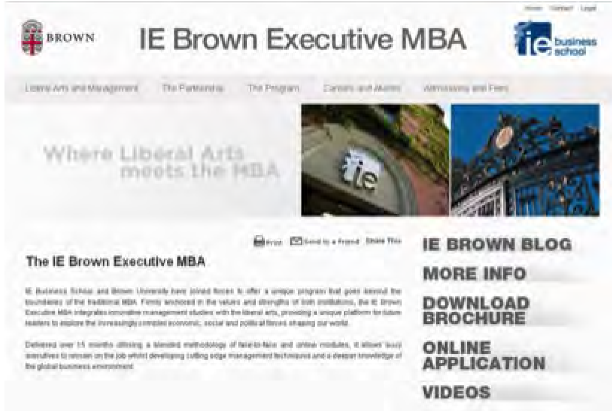
Over the coming decades UK economic policy is likely to focus on promoting the knowledge economy and on design and manufacturing. Higher education will play a key role in achieving these strategic goals, by teaching the right skills and through the provision of commercially oriented research that meets changing industry requirements. HEIs must ensure that sufficient numbers of graduates are produced in order to feed the labour market with prospective employees boasting the right qualifications, skills and talents. New types of knowledge-driven value creation and a shift towards open innovation are increasing employer demand for new types of skills in addition to relevant qualifications. In a world dominated by information and the analysis and interpretation of data, future employees will need to be able to process complex information and solve problems. They will also need important intangible or "soft" skills. The ability to adapt to new situations, generate new ideas, engage with others and solve unexpected problems is crucial in the knowledge economy. Soft skills become even more important as technical work is increasingly handled by computer. Listening, relationship building and creative collaboration are all skills that will be much in demand, all of which depend on effective communication between people.



DeVry University

DeVry University is an example of a university with a strong focus on career-orientated teaching. Courses are already tightly linked to industry requirements and responsive to emerging needs.

For example, courses on cybersecurity are a direct response to growing industry concerns about cyberattacks and cybercrime. Other courses on offer include biomedical engineering.



IE Brown MBA Programme

IE Business School and Brown University have joined forces to offer a unique programme that goes beyond the boundaries of the traditional MBA. This new MBA programme integrates innovative management studies with the liberal arts, humanities, social sciences, engineering and life sciences to provide a distinct platform for future leaders to explore the increasingly complex economic, social and political forces shaping the world. Delivered over 15 months utilising a blended methodology of face-to-face and online modules, it allows busy executives to remain on the job whilst developing cutting-edge management techniques and a deeper knowledge of the global business environment.

This is also a good example of collaboration between different organisations, bringing together the best attributes of each to create a product that's greater than the sum of its parts.

HEI response

In response to changing needs of employers, various forms of learning will be required to produce rounded, resourceful, "work-ready" employees. This could mean the future adoption of new learning environments and forms of assessment in education systems.

HEIs will need to focus on teaching transversal competencies and providing facilities and courses that support cross-pollination and a breakdown of silos. Industrial and business innovations are increasingly driven by collaboration across diverse disciplines, leading to new fields of research such as nanoinformatics and biotechnology.

We may also see humanities play a role in the teaching of sciences and vice versa, for example, in order to develop more creative scientists and to empower humanities graduates to become creative drivers in science.

Holistic, interdisciplinary learning will also be a key feature of future studies, as systemic thinking becomes standard practice in business and industry.

Corporatised curricula

Over the coming years, many governments around the world will struggle to provide the same financial support to higher education that they have been giving in the past. In addition, HEIs will have to compete internationally more than they do currently, a situation that will be exacerbated by the rapid increase of new commercial providers in other regions.

Solutions that HEIs will consider may include diversifying revenue streams, increasing tuition fees, expanding abroad, attracting more lucrative overseas students, engaging in public-private partnerships or scaling up paid-for services in research. Another option is to engage in greater interaction with private sector organisations in their home territory and overseas.

Greater cooperation between universities and the private sector could lead to the rise of the corporate campus, giving companies more control over the process of matching graduate skills and capabilities with changing employer requirements. This approach will also engender a greater degree of loyalty from their future employees, something that will be valued more as attitudes to careers change to become more transient and mobile. As a result, corporate-sponsored programmes, buildings and departments will be a more common aspect of the future campus.

"The reform of education and the future of work are intertwined, and being perceived as such will allow for the creation of an interactive collaborative atmosphere with immediate feedback and development.

"I think that when you look at what's going to be happening in higher education in the next 20 or 30 years and the pressure to do public-private partnerships you're going to see more and more private entities working with universities."

Doris Helms, former provost of Clemson University

Tweets

carolinnepennock C. Dodds Pennock
Two-thirds of UK employers surveyed wd hire a school-leaver with two years' work experience over a #university graduate
http://t.co/Nwe3QdU

skillsontap Skills On Tap
Ofsted proposes changes to inspection of further education and skills to improve learners' employability **http://ow.ly/6iFIG** | Ofsted

FUTURE CAMPUS NARRATIVES

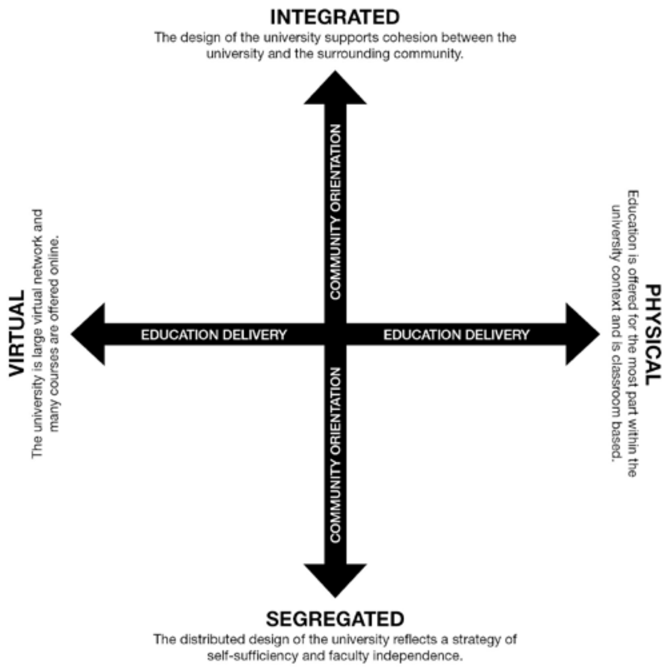
The Campus of the Future scenarios that follow are the result of collaboration among MA Creative Practice for Narrative Environments, Central Saint Martins College of Art and Design, University of the Arts London and Arup's Foresight + Research + Innovation (F+R+I) team.

As part of this work, the F+R+I team invited students from MA Narrative Environments to research and produce scenarios for the Campus of the Future.

The aim of this industry collaboration was for students to learn about different forecasting methods and tools with which to envision the world in 2030. The challenge was to synthesise complex and diverse research material into an engaging narrative format to create a set of four divergent yet equally plausible visions of what the campus might look like 15 years from now.

Students were asked to explore either a digital or physical campus format coupled with either fully integrated or segregated characteristics (town versus gown). These diametric poles have been visualised in the research methodology matrix to the right.

The outcome of this work has been four narratives using mixed media, including storyboards, animations and videos. Each expresses different scenarios for the Campus of the Future. Collectively, they focus on unique learning environments for future students and how changing student expectations influence future design. Special attention was paid to the emerging Internet of Things and sustainability, and to how "digitized" students might impact upon future campuses.



Export Yourself University

Digital / Town Virtual / Integrated

Alex Goller, Sam Lofgren, Eva Xie

The scenario depicts a world taken over by the digital. Resources are scarce and human labour is increasingly replaced by robots and automation. As a result, more and more people are unemployed and confined to a digital existence. People's brains are equipped with sensors that convert and artificially enhance their experience of the world: tofu — the world's staple diet — is turned into a tasty steak at the touch of a button. The story centres on Ming, a 50-year-old mechanic from Beijing. Ming is replaced by a machine and suddenly unemployed. He is frustrated that his skills are no longer needed in this digital world. However, he does not want to confine his life to digital experiences and desperately needs some income to support his love for urban farming — his only access to natural food. He searches for global jobs for mechanics and discovers a vacancy in Tanzania, supported by EYU — Export Your University. He immediately starts a digital learning course designed to introduce students to African culture and language. The orientation period takes place in a virtual environment, where Ming learns the language and culture required to do his new job. The learning environment lets the user enter a holographic environment that teaches about day-to-day encounters. During his training he receives his first job offer, working freelance, remotely supporting a farm with its technical problems. Instead of taking money, Ming asks the farmer to send him seeds to support his urban farm back in Beijing. Ming slowly falls in love with Africa and wants to turn his digital experience into real-world physical encounters. With job prospects looming he finally makes a decision to leave his digital life in China to start a new physical Second Life in Africa.

Storyboard: http://www.scribd.com/doc/79262752/EYU-SRORYBOARD

Ian's Journey

Digital / Gown Virtual / Segregated

Philip Nicholson, Wang Wang, Shan Hu, Gijs Leijdekkers

The scenario depicts the journey of Ian. Ian first enrolled at the Digital University for Global Innovation (DUGI) back in 2030. DUGI started as an open source education algorithm. Ian's university experience starts when he moves into a small white room — his personal holographic learning environment. The room provides fully personalised holographic teachers and offers a variety of customized learning modules. The system automatically recognises personal interests and capabilities to create learning experiences that are perfectly tailored to student requirements. However, Ian is not happy in this artificial, isolated environment. When Ian starts to virtually connect to other students, he starts falling in love. He soon gets frustrated by not being able to physically meet with his new-found friend. He starts to feel really trapped in his room. He eventually breaks free from his holographic environment to discover that his love has actually been living in a similar white room just next door. Ian decides to use his negative experience to update the DUGI environment into an experience that resembles a narrative learning environment, which combines physical facilities with the benefits of digital learning. Ian is now a lecturer and provides induction courses to new students.

Video: http://vimeo.com/23360466

Beyond Walls

Physical / Town Physical / Integrated

Katie Russell, Victor Heynemann Seabra, Oliver Tsai

More than half of the world population already lives in cities. Over the coming decades the proportion and number of people living in urban environments will continue to grow. As a result, cities will be increasingly important spaces for both education and employment. Challenges around infrastructure provision, urban mobility and environmental sustainability will also impact the shape of future campuses, for example, increasing demand for localised education facilities — such as education hubs or coworking spaces — that decrease the need for inner-city commuting and make higher education accessible to local communities.

The scenario takes place in an overdigitalised world. The story begins with an introduction of Beyond Walls: a new type of university that markets itself as a flexible solution to the difficulties of everyday life, characterised by overcrowded public transport systems and constant exposure to advertising. The main character is Pura. She is anxious and worried about the security of her job. Beyond Walls offers a flexible approach to learning focused on traditional values such as face-to-face interactions between students, learning by doing and access to local facilities and business communities. Beyond Walls is designed for ambitious people who work and live hectic and mobile lifestyles. It is a university that focuses on lifelong learning through flexible personalised modules specific to student needs. There are lots of learning hubs all across the city, which enable local interaction with other students, reducing the need to travel across the busy city. This especially appeals to Pura, as it gives her a chance to escape from the chaos of the city.

Video: http://vimeo.com/23358585

Bioflame University

Physical / Gown Physical / Segregated

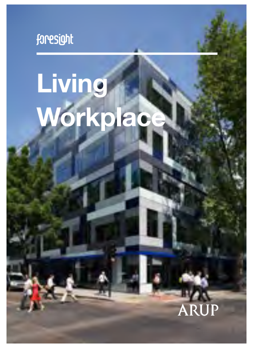
Antonia Grant, Sumedha Garg, Veronika Schurr, Rachel Mikulsky

The scenario describes an education system in a world characterised by overpopulation and pollution. Spaces for physical universities are rare, so most students attend the much cheaper and more accessible Cyber University. The story is about Samantha, who is considered one of the lucky few to have won a place at Bioflame University — an isolated university campus made up of a self-contained ecosystem located in the outskirts of London. In contrast to the crowded and dirty urban megacities that most people live in, Bioflame is a place with fresh clean water and lots of natural space. However, this comes at a price as students are highly controlled and monitored. Bioflame is run by a private corporation, whose ultimate goal is to harness student intelligence to create better products. It is a future learning environment characterised by corporate power, where students have to conform to strict rules and deliver results for the company as part of their education contracts.

Video: http://vimeo.com/23358115

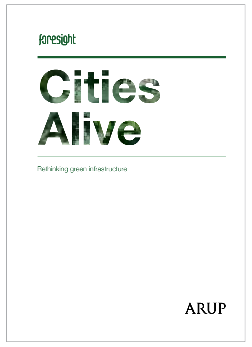
Publications

The Future of Retail explores how drivers of change are shaping the future of retail. It reveals important trends shaping new consumer behaviours and looks at some of the likely impacts that these will have on future retail environments and services.



Living Workplace focuses on the future of the workplace. It investigates the impact of growing cultural and generational diversity, the role of new technologies and working patterns and the importance of creativity and collaboration for organisational success.

Moving beyond static objects in glass cases, *Museums in the Digital Age* outlines how future museums will see personalised content, new levels of sustainability and a visitor experience extended beyond present expectations of time and space.



The ideas being developed in *Cities Alive* seek to capture not only the beauty of nature but also the sustainability of balanced ecosystems. These are challenges for landscape designers creating new cities that meet our increased expectations for access to clean water, cheap and plentiful supply of food, and fast and effective transport systems, with the need to reduce the impact on natural resources.

The Future of Rail 2050 focuses on the passenger experience and sets out a forward-looking, inspiring vision for rail. The user journeys imagined here are intended to generate a conversation about the future and provide the big-picture context for future planning and decision making by governments and the rail industry.

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pg 20 Quinn Dombrowski, CC BY-SA 2.0

What expectations will students have in the future, and how will they want to learn? Over the coming years and decades, the student body will undoubtedly become more diverse as a greater number of mature students enter higher education looking to develop skills, enhance employment prospects or change career paths. Economic growth in emerging economies will continue to raise income levels over time, leading to an increase in the number of foreign students looking to study abroad. This will intensify the need for higher education institutions in more advanced economies like the UK to cater to varied cultural backgrounds, different learning styles and a broader range of interests.

Campus of the Future highlights the Arup Foresight + Research + Innovation team's opinion on the future of the campus. It summarises some of the key drivers of change and gives examples of innovative campus environments, both physical and digital, that are leading the way around the world.

ARUP

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arup.com
driversofchange.com

mars 2014-03-28

Birgit Cold

Tittel

NTNU og Trondheim Midtby - utvikling av et bymessig integrert universitet for de neste 50 år.

Ingress:

Kan vi forestille oss utvikling av NTNU og Midtbyen i en bymessig struktur som tar vare på eksisterende arkitektoniske og landskapelige verdier, legger til rette for faglig, sosial og kulturell integrering og dermed skaper nye verdier for de neste 50 år?

Forestillinger om NTNU som sted i fremtiden.

Et steds identitet

Et steds identitet er samspillet mellom de fysiske omgivelsene, det som foregår og våre forestillinger om nettopp disse to fenomener. Dette skriver psykologen D. Canter (The Psychology of Place, 1977). Jeg vil her fabulere over hvilke positive og spennende forestillinger man kan ha om de neste 50 års utvikling av NTNU som universitet i Trondheim med Gløshaugen som utgangspunkt og Midtbyen som magnet.

Forbilder som har gitt oss positive opplevelser ligger ofte til grunn for våre forestillinger. Oxford University med sine mange arkitektonisk verdifulle bygninger og sine studentbosteder – colleges – i en bystruktur med sosiale og kulturelle tilbud, med parker, grønne gårdsrom og livlige gater med vakre bygninger, gir oss positive opplevelser. Universitetet er en integrert del av byen Oxford med alle dens attraktive spise- og drikkesteder, klubber, bibliotek, musikk- og konsertlokaler, butikker og meget annet. Universitetsbyen Lund i Sverige har i den gamle bydelen samme attraksjon som Oxford. Blindern i Oslo, Chalmers Tekniska Högskola i Göteborg og Danmarks Tekniske Universitet langt utenfor København, er universiteter som fremstår som egne bydeler uten integrasjon med nærliggende by og uten kulturelle og sosiale møtesteder på kveldstid. Bydeler som er mørklagte på kvelden og med tomme gater. Slik oppleves også NTNU på Gløshaugen og Dragvoll. Disse beskrivelser er basert på opplevelser og ikke en analyse av de nevnte høyskoler og universiteter.

Skolemiljø – fire fortellinger, Kommuneforlaget, 2002

Etter i en årrekke å ha forsket på både grunnskolen og den videregående skolens ofte trauste fysiske fremtoning og skolemiljø, bestemte jeg meg for å beskrive steder jeg har opplevd som spesielt attraktive og som kanskje kunne virke som inspirasjon for utvikling av skoler og deres miljø. Jeg diktet fire fortellinger:
Skolen som veksthus, hvor skolens miljø foregår i en atmosfære preget av grønne vekster, av dagslyset som trenger ned gjennom det grønne, av åpenhet og av slanke konstruksjoner.

Skolen som senter i en liten by hvor alle verksteder, spisesteder og lokaler hvor det skapes og produseres ligger ut mot torget og gatene som er fulle av sosialt liv og kulturelle hendelser, mens kontorer, stille arbeids- og studieplasser ligger i etasjene over.
Skolen som basargate inspirert av de arabiske basargater hvor både varen, produksjonen, materialene med farger og lukter eksponeres og kundene får innsikt i det som produseres og kan kjøpes. Et skolemiljø hvor elevenes aktiviteter er synlige for alle.
Skolen som en stor åpen utstillingshall. Et stort rom med masser av dagslys, som vi kjenner fra de store markedshaller. En slik hall innredes og endres så den til enhver tid egner seg til det som skal foregå. En total fleksibilitet.
Stikkordene for de nevnte kvalitetene er: *Åpenhet, dagslys, det grønne og fleksibilitet.*

Dragvolls struktur med de glassoverdekte gatene for sosialt og kulturelt liv
Den danske arkitekt Henning Larsen som vant den nordiske arkitektkonkurransen om universitetsutbygging på Dragvoll, forklarte at inspirasjonen til de glassoverdekte gatene kom da han fra vinduene i sin tegnestue så ned på det kjente "Strøget" i København og tenkte at slik bør et universitets sosiale og kulturelle liv finne sted. Dragvoll universitetet er som struktur et kjempefint eksempel på de ovennevnte kvalitetene i fortellingene. Men Dragvoll ligger på feil sted, langt fra byens attraksjoner og langt fra de øvrige studentlærestedene. Utbyggingen med enkeltstående bygninger har også ødelagt ideen som Henning Larsen hadde for området. Kan vi la oss inspirere av Dragvoll som idé og struktur?

Universitetets estetiske fag som synlig attraksjon og invitasjon
Det er få ting som er så interessante som å se andre arbeide. De estetiske fagene på universitetet utmerker seg som attraktive å bli kjent med, iaktta, utstille og kanskje delta i. Tegne- og modellverksteder, atelierer og utstillingsrom, øvingsrom, arenaer og scener for dans, musikk og teater. Også verksteder for praktisk arbeid og vedlikehold inne og ute kan være interessante å kikke inn i. Vi kan forestille oss at både universitetets folk og byens borgere lar seg inspirere og vil ha lyst til å ferdes helt naturlig gjennom universitetets områder.

Hvor forestiller vi oss at NTNUs byutvikling kan finne sted over lang tid?

Vi peker på områder og steder hvor universitetets funksjoner kan utvikle seg i et langtidsperspektiv. Byen vår er liten, særlig Midtbyen, som det påstås lider under at folk foretrekker å handle andre steder og ikke bruker tid i byen. Kan universitetet utvikles fra Gløshaugen og Hovedbygningen langs Høyskolebakken ned til Studentersamfundet og videre over Elgeseter bro, eller på en ny bro med nær forbindelse til St. Olavs Universitetssykehus og med bygninger a la Ponte Vecchio i Firenze? Arkitekt S. Seablom lanserte denne ideen i 1985, da NTH ble 75 år. Eiendommer langs Elgeseter gate mot Midtbyen kan kanskje tas i bruk. Leüthenhaven, med fjerning av busstasjonen er et ypperlig sted for en større utbygging med offentlige glassgater med auditorier, kafé, pub og rom for de estetiske fagene arkitektur, design, bildende kunst, musikk, dans og teater. Altså et slags “nytt Dragvoll” midt i Midtbyen. Kan universitetet videre finne plass i eiendommer i Kongens gate frem mot torget? Kunne torget bli et felles byrom for byens borgere og universitetets brukere? Forestillinger og fantasi er medvirkende til innovasjon.

The School of the Future

— Heimdal Videregående Skole – A ZEB Living Lab

The environmental performance of buildings needs to be drastically improved, especially in terms of energy use and grenhouse gas emissions.

The Research Centre on Zero Emission Buildings (ZEB) has a vision to eliminate the greenhouse gas emissions caused by buildings. ZEB's new pilot project for Heimdal Videregående Skole will be used a basis for exploration and experimentation in this village.

This village will give you an opportunity to work not only on the physical aspects of design, such as the building itself, but you will focus on the wider issues of sustainability.

Relevant competency required

The village welcomes students from all study programmes. It is possible to work with both technical and non-technical topics, as well as, a combination of both. We are looking for students with different backgrounds and expertise who have an interest to learn and investigate topics would they would not usually study, as well as, a willingness to look at your own interests in the context of the bigger picture.

About the village

In this village, you will have an opportunity to work not only on the physical aspects of design, such as the building itself, but you will focus on the wider issues of sustainability. Such as the impact of our lifestyle choices, carbon footprint, sustainability through education of next generation etc. The issues related to achieving such a goal are not just design based and incorporate many other sustainability issues and above all human interaction.

A possible theme may be centred around how school children can be involved in developing an awareness of sustainability, both physically, by being involved in the developing concepts for their own sustainable school and non-physically, though involvement in the future development of their education and curriculum.

Course code: AAR4911
Village: The School of the Future: Heimdal Videregående Skole
Type: Semester-based
Language: English
Village supervisor: Aoife Houlihan Wiberg (http://www.ntnu.no/ansatte/aoife.houlihan.wiberg)
Contact information:
aoife.houlihan.wiberg@ntnu.no
Semester: Spring 2015

Important information about EiT:

- The focus on teamwork skills and group processes is the unique feature of Experts in Teamwork (EiT).
- EiT's educational method requires that every participant contributes and is present throughout the semester. For this reason, attendance is compulsory on every village day.
- In contrast to many courses, the first few days are especially important in EiT. During this period, the team members get to know each other and discuss what each individual can contribute. You will also draw up the compulsory cooperation agreement and start preparing a shared research question.
- For additional information about Experts in Teamwork, see the page for students. (https://innsida.ntnu.no/wiki/-/wiki/English/Experts+in+Teamwork+-+for+students)

For example, the building itself may be a living laboratory to provide interactive experiences for you to showcase, engage and gain feedback on different aspects of sustainability. You will need to develop an understanding of what sustainability means and what a living laboratory is. The students (and teachers) are expected to investigate ways of changing our current way of living and lifestyle choices towards achieving sustainability. This requires an interdisciplinary approach where students from different fields exchange their expertise/knowledge.

The village will use an ongoing competition for Heimdal Videregående Skole as a basis for the course. Marit Sollien of Heimdal VGS will come and talk to the students about the ongoing project and the remaining challenges.

Examples of research questions the student groups may use as a starting point:

- How can the learning environment be influenced by a more sustainable way of thinking?
- How can the school be a beacon of sustainability for the next generation, immediate community, society, education curriculum to be implemented at a national level?
- How is sustainability communicated? How can communication improve sustainability awareness, lifestyle choices, health etc. user feedback (iphone apps: moves, smart meters)
- What technical measures are needed to realise such a school?
- How can you (the students) contribute to the development of such a concept?
- How can the current competition entries be developed further to meet the ZEB ambition goals? What ideas could be implemented to make it a living laboratory and classroom for the students?
- Which is more important, greenhouse gas emissions or sustainability? Both? How are/can they be inter-related?
- How can developments and choice of building materials contribute to the development of a sustainable school of the future?

External partners:

ZEB
Professor Arild Gustavsen ZEB Centre Director and Professor Anne Grete Hestnes
Professor Thomas Berker ZEB Leader WP4 User behaviour

Heimdal VGS
Ms. Marit Sollien – Perspective from the Heimdal VGS school
Professsor II Inger Andresen – ZEB Heimdal Skole Pilot Project Leader

Other
Dr. Erica Lofstrom - User Behaviour - SINTEF
Bastian Klunde (ZERO) & Solveig Knudsen (Low Energy Programme)

Sources and links

http://www.zeb.no (http://www.zeb.no/)

http://www.enob.info/en/net-zero-energy-buildings/map/ (http://www.enob.info/en/net-zero-energy-buildings/map/)

http://zeb.buildinggreen.com/ (http://zeb.buildinggreen.com/)

http://www.cleanenergyactionproject.com/CleanEnergyActionProject/Zero_Net_Energy_Buildings_Case_Studies.html (http://www.cleanenergyactionproject.com/CleanEnergyActionProject/Zero_Net_Energy_Buildings_Case_Studies.html)




School of the Future

TOWARDS ZERO EMISSION WITH HIGH PERFORMANCE
INDOOR ENVIRONMENT

School of the Future

Fraunhofer IRB Verlag

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FURTHER INFORMATION
www.school-of-the-future.eu

Preface

The European climate and energy targets for 2020 require a reduction of the greenhouse gas emissions by at least 20 percent, an increase in energy efficiency by 20 percent and a 20 percent share of renewables in the total use of energy. The construction sector is expected to make a substantial contribution to achieve these goals. In addition to tightening requirements on new buildings (up to nearly zero energy buildings from 2019/2021 on) the focus must be on improving the energy performance of the building stock, as existing buildings account for the largest share of building energy consumption.

In the EU Energy Efficiency Directive, the European Parliament and the Council of the European Union have pointed out that national, regional and local institutions are to set good examples for achieving energy efficiency by defining ambitious targets for the overall energy performance of public buildings. These examples should also convince private building owners of the success and the importance of building retrofits. Regarding the selection of possible demonstration projects it was recommended to choose buildings which are seen and visited by many persons. Besides, there should be an option to use the experience gained in the renovation process for replication in other buildings. Schools are perfectly suited for this purpose as they are used and attended by broad sections of the population, people of different age and income. Pupils and teachers are given the opportunity to closely watch the renovation process and to experience its impact on the indoor environment for themselves. The implemented measures and the improvements achieved thereby are going to be addressed in special class lectures or in working groups. Since the pupils act as communicators to their families, the knowledge they transfer will lead to a multiplied impact of the school energy retrofits. After all, the children are going to be the decision makers, researchers and achievers of the future.

For these reasons, the EU FP7 'School of the Future' project was a very rewarding and very important demonstration project with regard to building energy retrofitting. The collaboration between different countries and between representatives of public institutions, partners from research and industry (which was also reflected in the international Design Advice and Evaluation Group) enabled the project partners to present ambitiously retrofitted school buildings, along with a multitude of other interesting project results like retrofit guidelines and computer tools.

Hans Erhorn
Fraunhofer Institute for Building Physics
Project Coordinator, 'School of the Future'

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School of the Future

Towards zero emission with high performance indoor environment

1 INTRODUCTION

In 2011, the ‚School of the Future‘ project was launched as a demonstration project in the Seventh Framework Programme of the European Union. The related call for applications focused on the 'Demonstration of Energy Efficiency through Retrofitting of Buildings'. Project goals included design, implementation and evaluation of holistic renovation measures in buildings with a high replication potential for large regions of Europe. The aim was to reduce the use of heating energy for the thermal conditioning of spaces in selected buildings by at least 75% through appropriate retrofitting measures. Accompanying measures were to include long-term measurements and an initiative to improve user behaviour. As the associated working programme was developed in cooperation with the Energy-Efficient Buildings - European Initiative of the European Construction Technology Platform (ECTP), partners from industry were encouraged to participate in the project.

The project proposal 'School of the Future' met these requirements, as the project focused on the renovation of four school buildings in four European countries with different climates. In addition to the public-sector building owners, five research institutions and four industry partners joined the project (see also the presentation of the project partners on page 38). In all of the four schools, the retrofits comprised measures to improve the building envelope, the building services systems and the use of renewable energy. The energy objectives defined by the project partners are as follows:

- Reduction of the heating energy use by 75% (as defined in the call)
- Reduction of the total energy use by factor 3 (i.e. by two thirds)

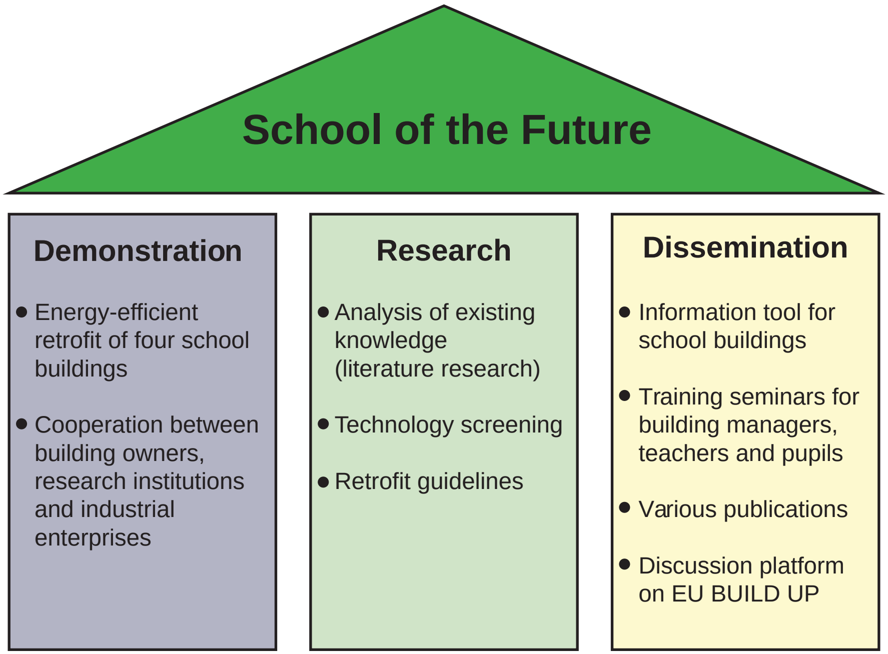
The total energy use includes space heating, water heating (DHW), ventilation, lighting and the residual use of electricity in buildings. None of the four school buildings needed cooling. The scope of the project included a monitoring phase of at least twelve months during which the energy consumption of the retrofitted buildings was measured. Subsequently, the measurements were continued by the building owners.

In addition to enhancing energy efficiency, the project also dealt with indoor comfort. Here, the target was to

- Improve the indoor environment to enhance pupils' performance

The analysis of the induced change in the indoor climate was based on short-time measurements and questionnaires. The four retrofitted schools are no zero energy schools, as this standard could not be realized without exceeding the envisaged energy-relevant investment costs of 100 €/m². Nevertheless, these schools use significantly less energy than specified in the national requirements for building renovation, thus leading the way towards even more energy-efficient school buildings. The further work packages in the project (the retrofit guidelines, for instance) demonstrate ways towards zero emission buildings or even buildings that generate surplus energy (energy surplus buildings).

The project was based on three pillars: demonstration, research, and dissemination. The outcome of the individual areas of work is summarized in the following sections. All results derived from the project are available on the project's website www.school-of-the-future.eu. The successful cooperation of the thirteen project partners was terminated according to schedule in January 2016.



Tasks of the School of the Future project

2 DEMONSTRATION BUILDINGS

SOLITUDE-GYMNASIUM, GERMANY

GENERAL BUILDING INFORMATION

ADDRESS	Spechtweg 40 70499 Stuttgart, Germany
BUILDING OWNER	City of Stuttgart
YEARS OF CONSTRUCTION	1966 - 1975
RENOVATION PERIOD	2012 - 2014
NUMBER OF PUPILS	710
NUMBER OF CLASSROOMS	27
REFERENCE AREA	8 924 m²

The Solitude-Gymnasium in Stuttgart-Weilimdorf was in need of renovation due to its high energy consumption. The school complex consists of several solid constructions: the main building, the building for science classes, the big pavilion and the gym. Between 2004 and 2006 the boilers had already been replaced; besides, the south-facing windows of the big pavilion, the roof of the main building and the roof of the gym had been refurbished.

Retrofit of building construction elements

In most cases, the existing windows were replaced with triple-glazed windows. The double-glazed windows of the big pavilion, which had already been renewed, were however retained. The upper part of the new external blinds can be controlled separately, thus ensuring good daylight supply even when the blinds are lowered.

Energy retrofitting of the external walls of the three school buildings included the installation of a curtain wall or an external thermal insulation composite system (ETICS). Insulation layers (between 14 and 18 cm) of mineral wool or rigid polystyrene foam were applied. The external wall of the gym was insulated using 18 cm mineral fibre boards.

U-values	Before retrofitting	After retrofitting
Roof	0.67 - 0.96 W/m²K	0.15 - 0.20 W/m²K
External wall	0.44 - 3.65 W/m²K	0.18 - 0.23 W/m²K
Windows	3.1 - 5.8 W/m²K	0.9 - 1.3 W/m²K
Floor	1.5 W/m²K	1.5 W/m²K

U-values of the building construction elements

The roof of the big pavilion was insulated using 14 or 16 cm expanded rigid polystyrene foam (EPS); the roof of the building for science classes was provided with a layer of 22 cm.

Retrofit of building services systems

Heating system: The gas boilers that had been installed in 2004 were combined with a cogeneration unit (CHP) to supply heat and electricity. This measure resulted in annual energy cost savings of EUR 10,000. This configuration uses the gas boilers for peak loads and redundant supplies. Besides, the thermal insulation of the heat distribution pipes supplying the gym was also improved.

Ventilation system: A centralised balanced ventilation system (supply and exhaust air) with heat recovery was installed in the assembly hall of the main building (heat recovery > 90%). The classrooms were provided with decentralized ventilation units (heat recovery > 80%). CO_2 sensors ensure a comfortable and healthy indoor environment. In the building for science classes, the existing central ventilation system was equipped with a heat recovery unit (WRG > 90%) and complemented by time-dependent and CO_2 dependent controls. The big pavilion is vented through windows that were provided with automatic actuators.

PV system: On the rooftop of the main building, 50 m² photovoltaic modules with a total capacity of 7.5 kWp were installed above the framework supports.

CHP unit, photovoltaic panels

Before retrofitting

After retrofitting

Lighting system: The old T8 fluorescent lamps were replaced with T5 fluorescent lamps; conventional ballasts were substituted by electronic ballasts. The light management is based on daylight-responsive control in the stairwell and on presence detectors.

Energy characteristics

On the base of calculations according to German standard DIN V 18599, the refurbishment of the Solitude-Gymnasium achieved the envisaged energy savings targets: after retrofitting, the need for delivered energy for heating was 75% less, while the total need for delivered energy was reduced by 74%. Regarding the school gym, the measured energy consumption data exceeded the predicted data. This deviation is due to the fact that it was not possible (for structural reasons) to provide the ventilation system with a heat recovery unit. Besides, about 270 refugees have been accommodated in the school gym since late summer of 2015. Given this situation, the actual user

Delivered energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	213 kWh/m²a	53 kWh/m²a	75 %
Electricity	12 kWh/m²a	10 kWh/m²a	17 %
Total	225 kWh/m²a	63 kWh/m²a	72 %

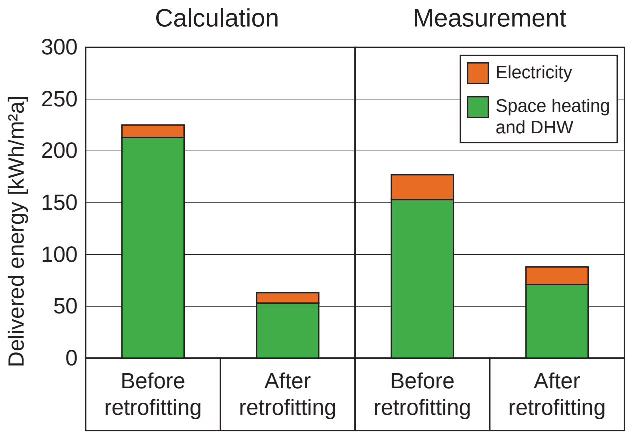
Primary energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	211 kWh/m²a	53 kWh/m²a	75 %
Electricity	34 kWh/m²a	24 kWh/m²a	29 %
Total	245 kWh/m²a	77 kWh/m²a	69 %

Delivered energy *Measurement*	Before retrofitting	After retrofitting*	Energy savings
Space heating and DHW	153 kWh/m²a	71 kWh/m²a	54 %
Electricity	24 kWh/m²a	17 kWh/m²a	30 %
Total	177 kWh/m²a	78 kWh/m²a	50 %

Primary energy *Measurement*	Before retrofitting	After retrofitting*	Energy savings
Space heating and DHW	151 kWh/m²a	70 kWh/m²a	54 %
Electricity	67 kWh/m²a	40 kWh/m²a	40 %
Total	218 kWh/m²a	111 kWh/m²a	49 %

*Space heating and DHW (Gas) PEF 1.1; Electricity PEF 2.8 / 2.4 / feed-in 2.8; (PEF = Primary Energy Factor, non-renewable); *Figures do not take account of the school gym*

Comparison of calculated and measured energy data



Delivered energy before and after retrofitting

profile is completely different from the profile that was assumed in the calculations and the profile before retrofitting. The need for continuous heating and the clearly higher air change rate prevented the planned substantial energy savings from being realised. The measured energy consumption of the school buildings alone is approximately as high as the predicted energy conservation potential of 72% savings in heating energy and 66% in terms of total delivered energy.

Indoor climate

The interviews concerning the quality of the indoor environment were carried out in February 2012 and in October 2015. After the renovation works were completed, users gave a more favourable evaluation of the indoor climate (for 15 out of 22 questions) regarding issues like the

- Indoor temperature in winter
- Indoor air quality in winter
- Daylight quality in the spaces

- Management of the sunshading devices
- Outdoor noise exposure.

The users assessed the indoor temperature and the indoor air quality of the main building in summer to be poorer than before retrofitting. As a consequence of the user survey, the air change rates of the decentral ventilation systems were increased. Besides, several windows which had been locked before were now made openable. The short-time measurements of the carbon dioxide level, of the temperature, the indoor air humidity and of the brightness in the spaces supported the users' statements.

Costs

The costs for the overall refurbishment of the Solitude-Gymnasium totalled approx. EUR 12 million or 1 340 €/m². These figures cover the energy-related costs, all other costs for the building measures and the planning costs, plus the rent for the containers (EUR 2.1 million) that served as temporary classrooms during the renovation of the main building.

Lessons learned

- Space limitations or structural restraints can prevent the implementation of efficiency measures, in this case e.g. the installation of the initially planned additional PV panels and the heat recovery in the gym.
- When installing ventilation systems, particular consideration should be given to the correct regulation. Besides, it must be ensured that the basal air change complies with the hygiene requirements.
- Due to the renovation measures the indoor air quality of the classrooms was significantly improved.
- Due to the conversion of the gym (now used as refugee accommodation) and the resulting significant changes in the usage profile the predicted energy savings for the gym could not be achieved.
- The measured energy data of the three school houses alone are ranging approx. in the order of the predicted saving potentials.

Dr. Jürgen Görres
Head of Department for Energy Management, Office for Environmental Protection, City of Stuttgart, Germany

“The Solitude-Gymnasium, which was built in the 1970s, was in need of renovation due to the high building age. It was decided to participate in the EU-project 'School of the Future' and the renovation works began in 2011. Thanks to the funding, the renovation scope of the school was extended beyond the measures required for the building's maintenance. Thus, the indoor air quality of the classrooms was significantly improved and the usable area of the school could be enlarged. Feedback from both students and teachers was very positive regarding the conversion work. Future school renovation projects in Stuttgart will definitely benefit from the experience gained in this project.”

TITO MACCIO PLAUTO SCHOOL, ITALY

GENERAL BUILDING INFORMATION

ADDRESS	Via Tito maccio Plauto, n. 4 47521 Cesena, Italy
BUILDING OWNER	City of Cesena
YEARS OF CONSTRUCTION	1960s
RENOVATION PERIOD	2011 - 2014
NUMBER OF PUPILS	380 - 400
NUMBER OF CLASSROOMS	33
REFERENCE AREA	6 027 m^2

The Tito Maccio Plauto secondary school complex comprises an L-shaped school building and a school gym, which are connected by a common entrance area. The building structure is made of reinforced steel; parts of the construction were done in exposed brickwork. The insufficient thermal insulation (including single-pane glazing) and the associated high energy consumption required energy retrofitting.

Retrofit of building construction elements

The old single-pane windows were replaced with PVC frame windows featuring argon-filled double-glazing. The windows now have a U-value of 1.2 W/m^{2}K. In addition, external blinds were mounted.

The external wall of the school building was provided with 12 cm of mineral wool as a component of an external thermal insulation composite system (ETICS). A layer of 10 cm mineral wool was mounted at the internal surface of the external wall of the school gym.

An insulating layer of 20 cm mineral wool was mounted at the top-floor ceiling of the school building and the roof of the gym. The lower surface of the basement ceiling was insulated with 10 cm polystyrene boards.

U-values	Before retrofitting	After retrofitting
Roof	2.3 W/m^{2}K	0.18 - 0.20 W/m^{2}K
External wall	1.8 - 2.8 W/m^{2}K	0.28 - 0.30 W/m^{2}K
Windows	5.9 W/m^{2}K	1.2 W/m^{2}K
Floor	1.3 W/m^{2}K	0.28 - 1.30 W/m^{2}K

U-values of the building construction elements

Retrofit of building services systems

Heating system: To supply the school buildings with space heating and hot water, three new gas condensing boilers working as a cascading system were installed, able to modulate the capacity between 13.4 and 215 kW. An additional natural-gas condensing boiler supplies the gym. Efficient electronic pumps distribute the heat to the radiators. By subdividing the building into different heating circuits (zoning), each zone can be individually conditioned and adjusted to a given time profile, supported by the newly installed radiators.

Ventilation system: Five independent mechanical ventilation systems with a heat recovery rate between 77% and 80% serve 23 classrooms.

PV system: A PV plant consisting of 250 m² monocrystalline photovoltaic modules with an overall capacity of 64.7 kWp was mounted on the inclined, south oriented roof surfaces. This allows for an electricity production of 68 000 kWh/yr. In the overall annual balance, this volume will cover more than the school's total electricity consumption.

Lighting system: The existing T8 fluorescent lamps were retained because their electricity consumption is low.

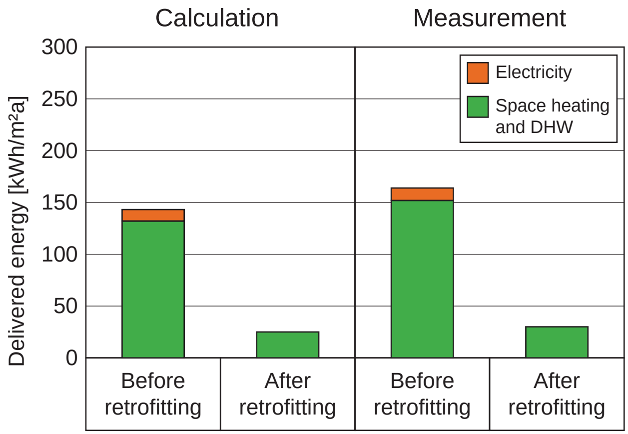
Condensing boiler, photovoltaic panels

Before retrofitting

After retrofitting

Energy characteristics

The refurbishment of Tito Maccio Plauto School accomplished the envisaged energy conservation goals, both in terms of predicted and measured consump-tion data: after retrofitting, the measured consumption of delivered energy for space heating and DHW was 80% less, while the total use of delivered energy was reduced by 82%. Based on measurements, 83% of the total primary energy could be saved.



Delivered energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	132 kWh/m²a	25 kWh/m²a	81 %
Electricity	11 kWh/m²a	0 kWh/m²a	100 %
Total	143 kWh/m²a	25 kWh/m²a	83 %

Primary energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	145 kWh/m²a	28 kWh/m²a	81 %
Electricity	24 kWh/m²a	0 kWh/m²a	100 %
Total	169 kWh/m²a	28 kWh/m²a	83 %

Delivered energy *Measurement 2014*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	152 kWh/m²a	30 kWh/m²a	80 %
Electricity	12 kWh/m²a	0 kWh/m²a	100 %
Total	164 kWh/m²a	30 kWh/m²a	82 %

Primary energy *Measurement 2014*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	167 kWh/m²a	33 kWh/m²a	80 %
Electricity	26 kWh/m²a	0 kWh/m²a	100 %
Total	193 kWh/m²a	33 kWh/m²a	83 %

Space heating and DHW (Gas) PEF 1.1; Electricity PEF 2.17;
(PEF = Primary Energy Factor, non-renewable)

Comparison of calculated and measured energy data

Indoor climate

The surveys on the quality of the indoor environment were carried out in February 2012 (with 291 pupils and 24 teachers participating) and in March 2015 (180 pupils and 9 teachers). After retrofitting, several aspects of the indoor climate were rated significantly better, namely the

- Indoor temperature in summer
- Indoor temperature in winter
- Indoor air quality in summer
- Outdoor noise exposure
- Daylight quality in the spaces.

Users felt that the indoor air quality in winter had only slightly improved compared to the situation before retrofitting. The short-time measurements on indoor climate confirmed the results of the interviews.

Costs

The net costs for the energy-relevant retrofitting measures (boilers, controls, mechanical ventilation, PV) including required certificates and fees amount to EUR 954 800 or 158 €/m². This amount includes all measures that were performed at the building envelope and the building services systems (e.g. the boilers, the ventilation system, and the photovoltaic system).

Lessons learned

- The energy target values for the retrofit of Tito Maccio Plauto School could be accomplished.
- The project shows that comprehensive refurbishment allows achieving energy savings of approximately 80% in public buildings.
- Due to retrofitting, the indoor environment quality in the classrooms was significantly improved. This is particularly true for the indoor air quality.
- With regard to electricity, the school is a surplus-energy school (in the annual balance).
- The successful demonstration project resulted in a new general retrofitting standard for the schools in Cesena.

Arch. Gualtiero Bernabini
Executive Manager of the Public Works Department of the Municipality of Cesena

“What Cesena has learned from the School of the Future project, will be used for future energy retrofitting projects and applied on existing buildings. Currently we're replicating the School of the Future knowledge on the San Vittore School and we are going to do it also in other buildings.”

HEDEGAARDS SCHOOL, DENMARK

GENERAL BUILDING INFORMATION

ADDRESS	Magleparken 8 2750 Ballerup, Denmark
BUILDING OWNER	Municipality of Ballerup
YEAR OF CONSTRUCTION	1972
RENOVATION PERIOD	2011 - 2014
NUMBER OF PUPILS	360
NUMBER OF CLASSROOMS	15
REFERENCE AREA	3 850 m²

The part F of Hedegaards School, with a building age of more than 35 years, was in need of refurbishment as the roof and the windows were leaky and the thermal insulation of the walls and the attic was insufficient. The electric lighting installations in the corridors were technically obsolete, causing high electricity consumption. Retrofitting included the thermal insulation of the building envelope, new windows, installation of more efficient lighting fixtures in the corridors and two classrooms, PV and a high-quality building energy management system .

Retrofit of building construction elements

The existing, contaminated windows (lead and PCB) were replaced with new triple-glazed windows mounted in insulated frames.

The external masonry work and the existing insulation layer were removed from the double-leaf masonry facade; the wall was insulated with 33 cm of mineral wool and provided with a new exterior layer (masonry or facing shell). Due to these measures, previously existing thermal bridges could be significantly reduced.

U-values	Before retrofitting	After retrofitting
Roof	0.45 W/m²K	0.06 W/m²K
External wall	0.57 W/m²K	0.10 W/m²K
Windows	3.1 W/m²K	0.70 W/m²K
Floor	0.40 W/m²K	0.40 W/m²K

U-values of the building construction elements

The roof was sealed and an additional insulation layer of 25 cm mineral wool was applied, which increased the total insulation thickness to 45 cm.

Retrofit of building services systems

Heating system: The connection to the district heating supply was maintained. The local district heat is mainly generated by waste incineration.

Ventilation system: The existing ventilation system was kept. It is now switched off in the offices outside normal working hours.

PV system: 152 m² of PV panels were installed on the roof of one of the school's roof light systems. With a total installed power of 22.5 kWp the annual electricity production amounts to approx. 22.5 MWh/yr.

Lighting system: As the existing lighting solutions in the classrooms already employed rather efficient T5 luminaires, retrofitting was restricted to two classrooms where two different LED systems were tested side-by-side. Here, the blackboard lighting was replaced with LED strips in a reflector. The corridors were supplied with two rows of LED downlights which use daylight-dependent controls.

Display of solar yield, LED lighting

Before retrofitting

After retrofitting

Energy characteristics

The calculated energy savings of Hedegaards School are in agreement with the project target values. The measurements performed in 2014 were adjusted with regard to climate. Heating energy savings were 60% (i.e. somewhat lower than predicted) while electricity savings were 29%, thus slightly exceeding planned values. The total savings of delivered energy achieved in the project are 123 kWh/m²yr or 57%. It should be noted that the set point of the indoor temperatures now is about 3 K higher than before retrofitting. Calculations proved that this influence approximately corresponds to the missing percentage of the savings.

Delivered energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	192 kWh/m²a	46 kWh/m²a	76 %
Electricity	22 kWh/m²a	18 kWh/m²a	18 %
Total	214 kWh/m²a	64 kWh/m²a	70 %

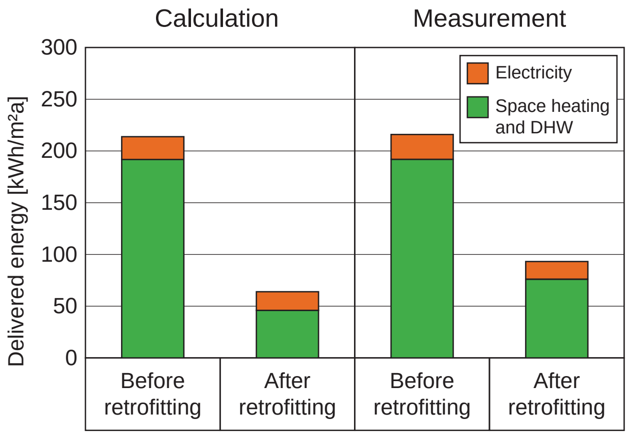
Primary energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	192 kWh/m²a	46 kWh/m²a	76 %
Electricity	55 kWh/m²a	18 kWh/m²a	18 %
Total	247 kWh/m²a	64 kWh/m²a	63 %

Delivered energy *Measurement 2014*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	192 kWh/m²a	76 kWh/m²a	60 %
Electricity	24 kWh/m²a	17 kWh/m²a	29 %
Total	216 kWh/m²a	93 kWh/m²a	57 %

Primary energy *Measurement 2014*	Before retrofitting	After retrofitting	Energy savings
Space heating and DHW	192 kWh/m²a	76 kWh/m²a	60 %
Electricity	60 kWh/m²a	42 kWh/m²a	30 %
Total	252 kWh/m²a	118 kWh/m²a	53 %

Space heating and DHW (District heat) PEF 1; Electricity PEF 2.5;
(PEF = Primary Energy Factor, non-renewable)

Comparison of calculated and measured energy data



Delivered energy before and after retrofitting

Indoor climate

The surveys on the quality of the indoor environment of Hedegaards School were conducted in May 2012 in three classes and in November 2015 in another two classes. The surveys contained questions about the indoor air temperature, the indoor air quality, the level of illumination and the quality of the light colour. The pupils found the situation after retrofitting to have improved in all areas. For instance, the quality of the light colour in the classrooms provided with LED luminaires was rated much better than the standard system.

Short-time measurements spanning one or two weeks were also performed before and after retrofitting. For this purpose, data loggers were placed in a classroom and in the corridor in order to record the carbon dioxide level, the indoor air temperatures and the humidity of the indoor air.

Costs

The overall investment for the energy-relevant part of the refurbishment amounted to DKK 4.1 million or EUR 549 000. Related to the floor space, this corresponds to 143 €/m². The simple payback time was calculated to be 17.6 years.

Lessons learned

- Positive experience has been made with the selected type of insulation for the double-leaf external wall (i.e. removing the outer leaf, applying the mineral wool and creating a new outer shell).
- The retrofitting process was carried out in several steps; each step involved two classrooms at a time. This worked out fine.
- The old windows were found to contain lead and PCB. This contamination raised the costs and required more time for window replacement.
- As replacing the classroom ventilation system was found to be too expensive, this measure was cancelled.
- The measured data of the energy savings are close to the predicted values and the targets of the project.

Mads Bo Bojesen,
Chief of Centre for Properties,
Municipality of Ballerup

"Over the past two to three decades Ballerup municipality has participated in several national and EU-projects with the aim of utilizing the results of research and development work in the design and construction of renovation works on the municipality's buildings with good results. Hedegaards School – built in 1972 – was in need of renovation, when the School of the Future project commenced, and the support from this project – both in the form of advice and economical support have made it possible to aim for and reach a much improved energy state of the building than otherwise foreseen. The renovation work went smoothly, the indoor climate has improved and the result is also aesthetically satisfactory."

BRANDENGEN SCHOOL, NORWAY

GENERAL BUILDING INFORMATION

ADDRESS	Ivers Holters gate 48 3041 Drammen, Norway
BUILDING OWNER	City of Drammen
YEAR OF CONSTRUCTION	1914
RENOVATION PERIOD	2011 - 2013
NUMBER OF PUPILS	370
NUMBER OF CLASSROOMS	25
REFERENCE AREA	7 079 m²

Brandengen School was built in 1914 and is a building of historical importance. The conservation authority permitted only marginal modifications of the original facade to be made during the renovation process. In spite of this strict requirement, the renovation measures included the replacement of the windows in addition to insulating measures at the attic and the installation of a geothermal heat pump.

Retrofit of building construction elements

All windows that had been installed after 1965 were replaced with triple-glazed windows fitted in insulated frames. The design of the new windows is much closer to the original appearance of the listed building. Due to a very low total energy transmittance (up to 27% only) it was possible to remove the solar shading devices (external blinds) that had been added during previous refurbishment and thus to better reproduce the original condition. Besides, some original windows in the corridor areas were restored.

The mansard roof in the heated zone and the top-floor ceiling were insulated with 30 cm of mineral wool. The roof above the attic was provided with ventilation openings to ensure dehumidification.

U-values	Before retrofitting	After retrofitting
Roof	1.15 W/m²K	0.20 W/m²K
External wall	0.85 W/m²K	0.81 W/m²K
Windows	2.6 W/m²K	0.8 - 1.0 W/m²K
Floor	0.19 W/m²K	0.15 W/m²K

U-values of the building construction elements

An additional insulating layer of 10 cm mineral wool was placed around the ventilation ducts in the attic.

A new drainage system and an insulation layer were mounted at the wall base.

Retrofit of building services systems

Heating system: A 200 kW heat-pump system with 19 geothermal heat pipes replaced the existing combination of two oil-fired boilers and an electric water heater. An oil-fired boiler was modified for the use of bio-oil and is now used to cover peak loads. In conjunction with the water heater this boiler also serves as a back-up system. During renovation, the gym was connected to the same heating system. Thanks to a complex system of compressors, condensers, liquid subcoolers and amply dimensioned heat exchangers, a seasonal performance factor of 3.1 could be measured despite the required high supply temperature of up to 70 °C.

Ventilation system: The ventilation system with heat recovery, which had been installed between 2001 and 2003, was maintained. The planned ventilation system for the school's gym was not implemented, as this building will soon be remodelled and become a classroom building.

Lighting system: The electric lighting system, which had also been renewed after 2001, comprises T5 luminaires provided with presence detectors. It was not modified in the project.

Heat pump, geothermal drilling

Before retrofitting

After retrofitting

Energy characteristics

Unfortunately, no measured energy consumption data was available for the period before retrofitting, due to the complex generation of space heating and

DHW by oil-fired boilers and an electric water heater. This is why the data measured after retrofitting can only be compared to the calculated values for the situation before and after retrofitting.

The savings of delivered energy for heating purposes (space heating and DHW) and the total savings of delivered energy achieved the target values required by the ‚School of the Future' project (both, predicted and measured data). It should be noted that the use of electricity could be reduced only marginally (calculation). Respectively, it has slightly increased (measurement). Neither the lighting system nor the ventilation system was modified in the scope of the project; there is no generation of electricity from renewables. Thanks to the renovation measures, the delivered energy for space heating and DHW could be reduced by 78%; the total delivered energy was reduced by 66%.

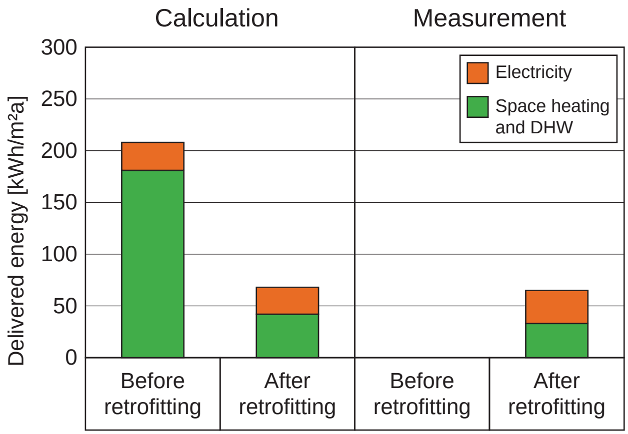
At present, assessments with regard to the primary energy are not general practice in Norway. It should

Delivered energy *Calculation*	Before retrofitting	After retrofitting	Energy savings
Heizung und Warmwasser	181 kWh/m^{2}a	42 kWh/m^{2}a	77 %
Strom	27 kWh/m^{2}a	26 kWh/m^{2}a	4 %
Gesamt	208 kWh/m^{2}a	68 kWh/m^{2}a	67 %

Delivered energy *Measurement 2014*	Before retrofitting	After retrofitting	Energy savings*
Heizung und Warmwasser	-	33 kWh/m^{2}a	78 %
Strom	-	32 kWh/m^{2}a	-19 %
Gesamt	-	71 kWh/m^{2}a	66 %

**Energy savings relating to the values that were calculated for the existing building before*

Comparison of calculated and measured energy data



Delivered energy before and after retrofitting

be noted that hydropower accounts for almost 100% of the electricity generated in Norway.

Indoor climate

The questionnaires on the indoor environment quality focused on indoor air temperatures, draught, and IAQ. The first survey was conducted before retrofitting in December 2011 (involving 41 pupils); the second after the windows had been replaced in January 2013 (46 pupils) and the third finally after completion of the retrofit in May 2015 (49 pupils). Each survey was done in two classrooms. After retrofitting, the pupils gave a much better evaluation of the indoor climate than before retrofitting. For instance, the share of pupils who perceived draught effects decreased from 31% to 9% after the windows had been replaced.

The indoor air temperatures, carbon dioxide concentrations and air change rates are continuously measured by the building energy management system.

Every three months, the measured characteristics are analysed using diagrams. Besides providing other information, these measurements prove that the carbon dioxide levels do not exceed the limit of 800 ppm.

Costs

The investment costs for the insulation measures, the new and the restored windows, the new heating pipes for the supply of the gym and the heat pump including the geothermal heat pipes amounted to a net total of EUR 1,093,000 or 154 €/m².

Lessons learned

- Usually, electric heat pumps cannot generate heating-water temperatures above 55 °C. The sophisticated concept of this heating system allows generating temperatures of up to 70 °C while still achieving a high seasonal performance factor of the heat pump. This concept is also suited for replacing high-temperature heating systems (e.g. oil-fired boilers).
- The heat pump has one alarm system for five sectors: condenser pressure, motor temperature, frequency converter, control sensor and two pressure switches, which complicates fixing problems.
- Daylight supply of buildings in northern countries should not be reduced by permanent shading devices. Thanks to the solar control glass applied at the southern and western facades, the former wind-sensitive external shading device could be removed. New solar control glass is characterized by low solar factors in combination with significantly higher light transmittances.
- The successful retrofit of Brandengen School was awarded several prizes and met with wide interest especially in the heat-pump solution and the replacement of windows in a historical building facade.

Paul Røland
Manager of Drammen Eiendom KF (Drammen Municipality's Real Estate Department)

“The authorities of Drammen municipality are focused on development of the urban environment, and are among the municipalities taking a national leading role in sustainable building. Participation in various programmes and pilot projects has given opportunities to develop our own expertise and working methods, setting frame conditions to stimulate climate friendly urban development and architecture of high quality. Drammen was appointed runner-up in the Nordic Energy Council Award 2011. By participating in the EU project 'School of the Future' Drammen municipality wants to contribute to raise the level of knowledge concerning retrofitting. Involving Brandengen School as a demonstration building, we are aiming to show that future high performance building levels are possible even in a historical building from 1914.”

3 DOCUMENTATION OF THE DEMONSTRATION BUILDINGS

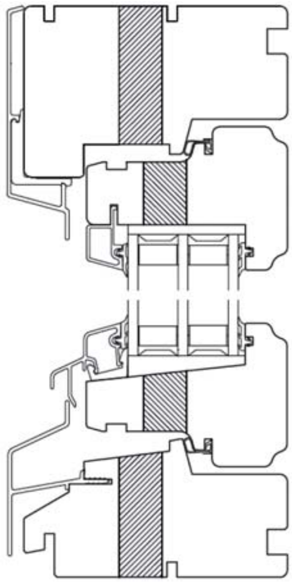
The four demonstration projects are documented on the project's website in different ways:

- Design Report: A report featuring the design and planning phases of the retrofitting projects
- Building Diaries: One building diary for each project illustrates the implementation of the retrofitting measures
- Final Demonstration Building Report: The final report on the completed retrofits summarizes the initial situation, the planning, the implementation and the evaluation.

In addition, the four exemplary case studies are described in the 'School of the Future' Information Tool.

Design Report

The Design Report focuses on the configuration of the buildings prior to retrofitting and on the retrofitting concept. In this context, the report features the building envelope (building construction elements), the heating system, ventilation and lighting, water heating (DHW), the use of renewables and the building management system (BMS) or individual control systems. A separate chapter analyses the influence of the Design Advice and Evaluation Group on planning and evaluation.



Design of the new NorDan passive-house standard windows for Brandengen School (Graphic: NorDan)

Building Diaries

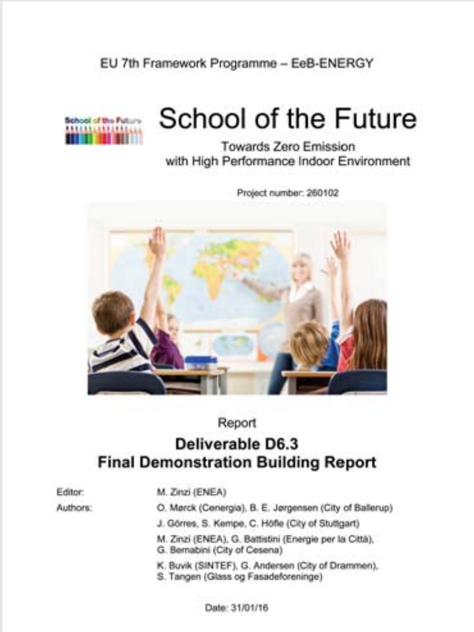
The building diaries contain descriptions and images documenting on-site inspections by the national researcher teams to report on the progress of the construction works and the implementation of key measures. For the Solitude-Gymnasium, for instance, the facade insulation of the main building is presented along with the attic insulation of the building for special classes and airtightness tests before and after refurbishment. Descriptions of the Italian project, Tito Maccio Plauto School, include the thermal insulation of the top storey ceiling, the facade insulation and the installation of the photovoltaic panels. Regarding Hedegaards School, project meetings and on-site inspections concerning facade renovations, PV modules, LED lighting, ventilation and building energy management system are documented. The diary for Brandengen School features the installation of heat pumps and new windows, the thermal insulation of the top storey ceiling and of the ventilation ducts.

Airtightness test at the Solitude-Gymnasium

Mounting the facade insulation at Hedegaards School

Final Demonstration Building Report

Besides covering planning and design, this report also includes the implementation of the retrofitting measures along with an analysis of the measured data relating to energy consumption and indoor comfort, thus evaluating the retrofitting concepts. The individual chapters of the report (each dealing with one school) are completed by a cross-evaluation.



EU 7th Framework Programme – EeB-ENERGY

School of the Future

Towards Zero Emission
with High Performance Indoor Environment

Project number: 260102

Report

Deliverable D6.3
Final Demonstration Building Report

Editor: M. Zinzi (ENEA)
Authors: O. Mørck (Cenergia), B. E. Jørgensen (City of Ballerup)
J. Görres, S. Kempe, C. Höfle (City of Stuttgart)
M. Zinzi (ENEA), G. Battistini (Energie per la Città), G. Bernabini (City of Cesena)
K. Buvik (SINTEF), G. Andersen (City of Drammen), S. Tangen (Glass og Fasadeforeninge)

Date: 31/01/16

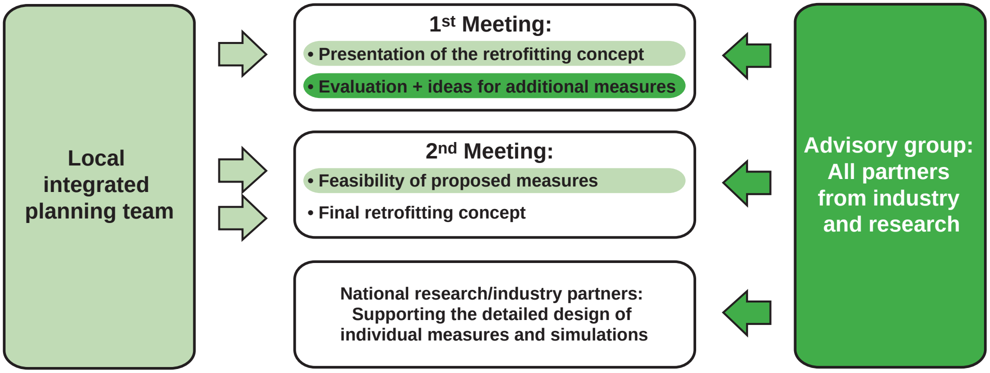
Front page of the Final Demonstration Building Report

4 DESIGN ADIVCE AND EVALUATION GROUP

The international Design Advice and Evaluation Group was established to support the local planning teams of the four renovation projects. This group comprised all partners from industrial enterprises and research institutions involved in the project. During the planning stage, the group met twice at every school. At the first meeting, the local planning teams presented their concepts for the retrofit while the advisory group contributed further ideas for additional energy-efficient retrofitting measures. The proposed measures were then reviewed by the local planning teams and incorporated in their concepts if considered appropriate. During the second meeting, the local planning team would explain why (or why not) the ideas could be included and the final retrofitting concept would be adopted. Among others, the measures given below could be proposed and eventually implemented:

- New light-coloured paint in the classrooms of the Solitude-Gymnasium
- Triple glazing at the Solitude-Gymnasium and triple glazing in a passive-house frame at Brandengen School
- Thermal insulation composite system (ETICS) also at the street front of Tito Maccio Plauto School
- Subdividing the heating in different zones at Tito Maccio Plauto School
- Tests of two LED lighting systems at Hedegaards School
- Building energy management system (BEMS) at Hedegaards School
- 30 cm of loose-fill insulation on the top-storey ceiling of Brandengen School

In addition, the national partners from the advisory group gave support regarding the detailed planning of individual measures and by providing energy simulations.



Cooperation of the local planning teams and the international advisory group

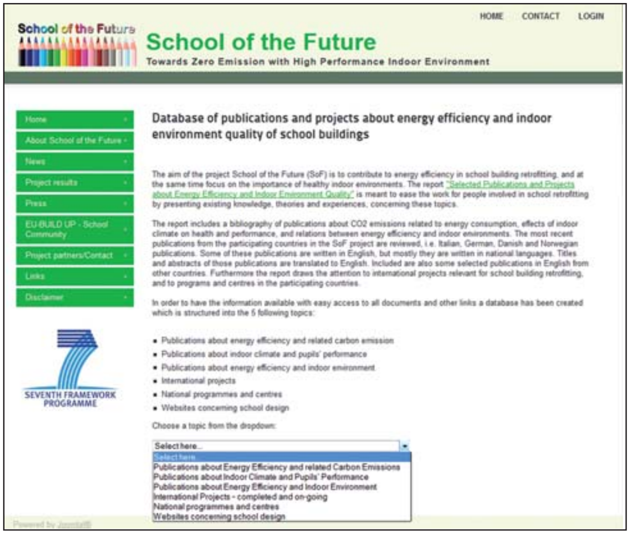
5 DATABASE ON SCHOOL PROJECTS AND SCHOOL PROGRAMMES

The 'School of the Future' project aimed at achieving substantial reductions in the energy consumption of the four schools through extensive retrofitting while improving the level of indoor comfort. As an introduction to the project (but also intended for use in other similar retrofit projects), a bibliography of publications related to national and international projects and schemes was compiled, featuring recent publications dealing with savings in energy consumption, carbon dioxide emissions, effects on indoor climate, health and performance, and relations between energy efficiency and indoor environments.

The results of the extensive literature survey are available on the website, both as a report and as a database. It is distinguished between:

- Publications about energy efficiency and related carbon emissions
- Publications about indoor climate and pupils' performance
- Publications about energy efficiency and indoor environment
- International projects
- National programmes and centres
- Websites concerning school design

The names of the authors, an English summary and the link to the respective source are provided for all sources.



Screenshots of the database on the project website

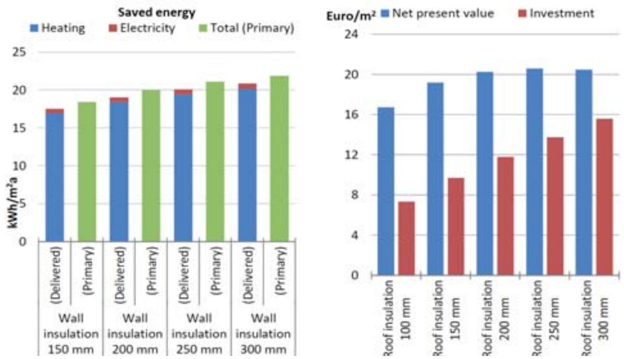
6 TECHNOLOGY SCREENING

The technology screening started with a compilation of the most important retrofitting measures concerning the building envelope and the building services systems. In a following step, these measures were evaluated with regard to energy, cost-effectiveness and indoor comfort, for up to three typologies of school buildings. For this task, the research partners adapted the initial condition of the schools, the efficiency of the retrofitting measures, the investment costs and the energy prices to the respective country. The calculations were carried out using the Danish calculation tool 'ASCOT', which is based on CEN standards. The 'ASCOT Light' version is also applied for the training of pupils.

The results of the calculations have been summarized in four national reports for Germany, Italy, Denmark and Norway. The reports cover the following technologies, mostly in several levels of efficiency:

- Roof insulation
- Floor insulation towards basement / crawl space / cellar
- Thermal insulation of external walls
- Window replacement
- Solar control glass
- Building energy management system (BEMS)
- Ventilation systems
- Lighting systems
- Photovoltaics
- Solar thermal water heating (DHW) and
- Heat generation systems like gas-fired condensing boilers, connection to district heat, electric heat pumps.

In addition, a package of the most appropriate measures was evaluated. The results are presented as saved energy (delivered and primary), achieved reduction of carbon dioxide emissions and investment costs. Also given are the net present value and the simple payback time compared to the lifespan of the respective measure. Regarding indoor comfort, the diagrams show the inner surface temperatures in winter and summer, the draught air speed, the radiant temperature, the dry-bulb temperature in summer and the carbon dioxide content of the air in winter and summer. The results of the screenings also provided basic data for the retrofit guidelines and the information tool. On account of the different national boundary conditions (like the defined initial situations, the climate or the prices) the measures are only partially comparable across the countries.



Saved energy, investment costs and net present value for insulating measures at the external wall of a Danish school

7 RETROFIT GUIDELINES

Based on experience gained from the school refurbishment projects within the 'School of the Future' scheme (including insights from further national and international school projects), the project team prepared four guidelines for school retrofitting projects (written in English), which are focused on the following issues:

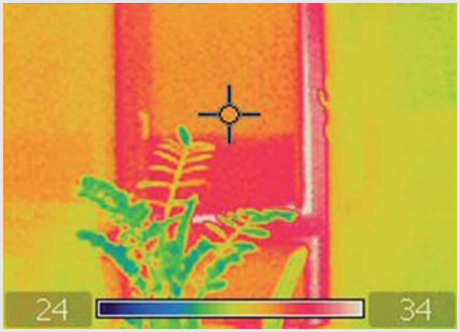
- Indoor environmental quality in schools
- Retrofit of building construction elements
- Retrofit of building services systems
- Solution sets for zero emission / zero energy schools

Retrofit guidelines

The guidelines are intended to support decision makers and planners in targeting, planning and implementing ambitious school retrofitting projects. The following requirements, measures and technologies are discussed in detail:

Indoor environment quality in schools

The section on 'thermal indoor climate' describes the thermal comfort requirements in winter and summer conditions. These include the operative temperatures, and in winter the prevention of radiation asymmetries due to cold surfaces and the avoidance of draught effects. In summer, heat gains must be avoided whenever possible.



Thermographic image of a meeting room - inside view on facade

In addition, strategies for passive cooling are presented, like increased ventilation, night ventilation, and the use of ground ducts for pre-cooling supply air. Further, various control systems for heating and cooling systems are discussed.

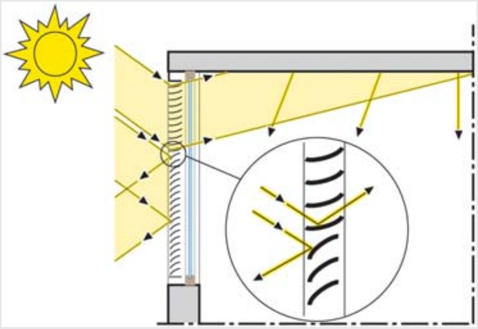
The chapter on indoor air quality starts with a compilation of the requirements relating to organic chemicals, to the prevention of emissions, to the carbon dioxide level and the hygienic ventilation rate. Later on, the chapter deals with ventilation strategies like natural ventilation, mechanical ventilation and hybrid ventilation, concluding with a presentation of various ventilation control options suited for school buildings.

Having treated the comfort requirements, the section on 'Lighting conditions' proposes strategies for the use of daylight, energy-saving technologies for artificial lighting and various types of lighting control systems. Besides addressing requirements like protection against external noise and structural noise control measures, the chapter on acoustics also includes information on noise emission from technical building systems. In addition, requirements for high-quality classroom acoustics and strategies for achieving good room acoustical properties are explained.

Retrofit of building construction elements

The retrofit guideline for building construction elements introduces the reader to planning and design strategies for energy-efficient buildings, recommending possible targets, early-stage definitions and integral planning. This guideline deals with important steps in planning, the consideration of environmental influences, tendering and contracting, even mentioning motivation and control of the subcontractors involved.

The retrofitting technologies are divided into non-transparent (opaque) building components and transparent components. Regarding the opaque parts, it is first discussed whether the additional insulation layer should be applied internally or externally, which materials are available and where vapour barriers should be used. In terms of wall and roof insulation, it is distinguished between light-weight and solid constructions. Avoiding air leakages and minimising thermal bridges are other major topics addressed.



Blinds with daylight redirection function

In the section on transparent building components the energy impacts of windows are specified. Information is given on available frames and spacers and on the impact of windows on daylighting and indoor thermal comfort. The section on glazing covers solar control glass, low-E glazing and electrochromic glazing, including light wedges and retrofit solutions featuring double skin facades. The problem of external condensation is addressed and there is a paragraph on heat loss as a function of wind speed and temperature. The chapter on solar shading systems describes the available technologies and the interaction of shading devices with daylight.

Further chapters deal with the influence of interior building elements on thermal comfort, the option of using phase change materials and the impact on acoustics. At the end of the guideline, the results of the technology screenings are summarized (for each technology covered) with regard to energy performance, investment costs and life cycle costs for the participating countries Germany, Italy, Denmark and Norway.

Retrofit of building services systems

The guideline for energy retrofitting of the building services systems in school buildings features the five main technologies given below:

- Condensing boilers
- Heat pumps (air-to-water / ground-to-water / water-to-water and air-to-air)
- Ventilation systems (mechanical ventilation / hybrid ventilation)
- Lighting systems (incandescent lamps, fluorescent lamps, discharge lamps, LED)
- Photovoltaics (different systems and building integration)

The guideline starts with an introduction of each technology, followed by a description of its functionality. Subsequently, the respective advantages and disadvantages are compiled and the technology's market penetration is analysed. The results of the technology screenings regarding energy savings in school buildings are summarized, and the cost-efficiency for each country is given. Applications in the scope of the 'School of the Future' demonstration projects are presented, conclusions are drawn and related literature is given.

Ventilation ducts at Tito Maccio Plauto School

Solution sets for zero emission / zero energy schools

The first part of the guideline for the development of zero emission / zero energy and even energy-surplus schools explains the three different levels of energy performance. In the following part, the strategies and technologies that are required to achieve these levels are specified for the categories of building design, building envelope, building services, equipment used in school buildings and energy generation from renewables, i. e. photovoltaics and wind turbines. Another issue addressed is the importance of presenting and discussing the completed projects in school lessons. Subsequently, two types of exemplary case studies are presented in detail:

- Zero emission/ zero energy schools or energy surplus schools
- Schools on their way towards becoming zero energy schools

For the second group, calculations are done to determine which size a photovoltaic array must have in order to make the schools zero-energy buildings (i.e. achieve zero energy standard in the total annual energy balance). This section also comprises the 'School of the Future' demonstration projects. In conclusion, the most commonly used solution sets for zero energy and energy surplus schools are identified, which are then presented as solution statements.

All retrofit guidelines include numerous examples of measures that were applied in the demonstration projects within the 'School of the Future' project.

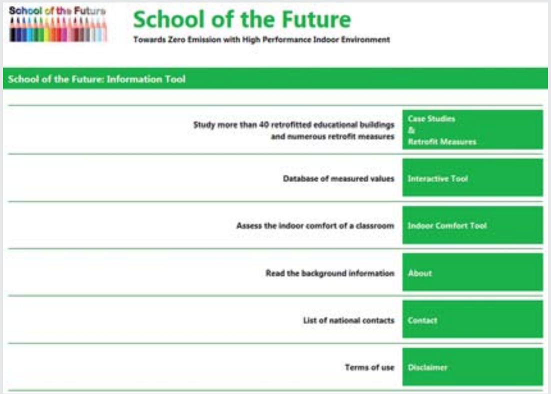
Energy surplus school 'François Mitterrand' in Montpellier

Energy surplus school at Hohen Neuendorf

8 INFORMATION TOOL

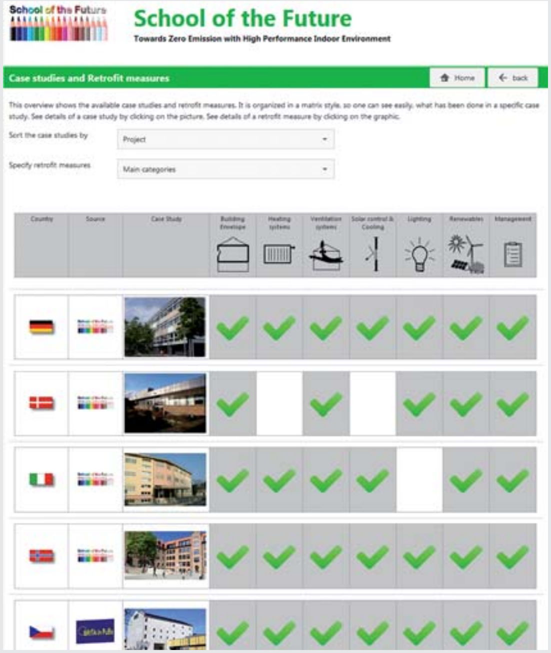
This internet-based tool provides decision makers and technical staff of public authorities with a wide range of useful information for the energy-efficient renovation of school buildings.

- Case studies presenting successful energy retrofitting solutions for educational buildings
- Explanatory notes relating to renovation measures
- National benchmarks for the comparison of characteristic consumption values
- Indoor comfort parameters for classrooms



Information tool menu

Besides providing purely informative parts (case studies and retrofitting measures) the tool also comprises interactive resources, which enable the user to compare self-measured characteristic values to mean values and requirements.



Case studies and retrofitting technologies are presented in a matrix

Case studies

More than 40 retrofitted educational buildings (mainly schools) are presented; each project is described in detail according to a given common structure. This matrix includes general data, the climate of the location, the building typology, the building‘s condition before retrofitting, the retrofitting concept, the energy consumption measured after retrofitting, evaluations by users, investment costs, experience made so far and reports for further reading.

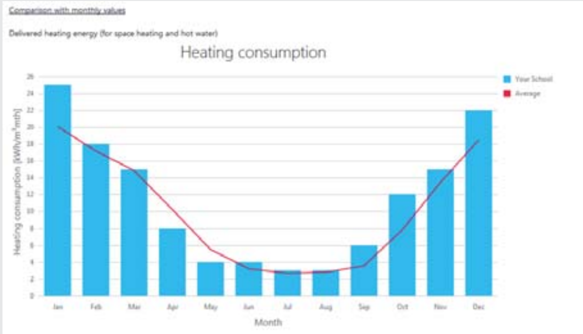
The featured projects are part of the 'School of the Future' project, of the EU project 'BRITA in PuBs' (Bringing Retrofit Innovation to Application in Public Buildings) and of Annex 36 'Retrofitting in Educational Buildings', conducted by the International Energy Agency (IEA) in the sector of 'Energy Conservation in Buildings and Communities'.

Renovation measures

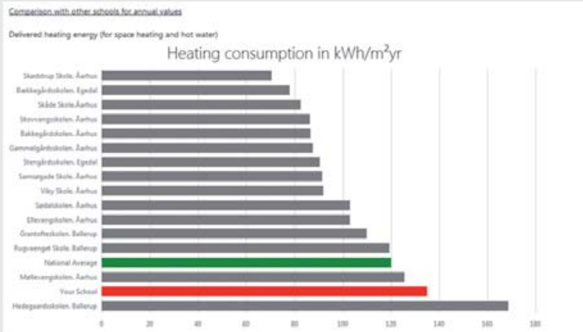
Information is given on renovation measures of the building envelope, the heating system, the ventilation system, solar shading devices and lighting installations, further on the use of renewables and on non-technological measures. This includes information about individual technologies as well as innovations in the relevant area. The technology screening results supplement the explanations and illustrate the volume of possible energy savings along with the cost efficiency of the measures.

Comparison of consuption values

The interactive tool enables the user to enter (annually or monthly) measured data on the heating energy consumption (space heating and water heating), on the consumption of electricity (ventilation, lighting and equipment) and on the water consumption of a specified school, which may then be compared to national benchmarks. Bar diagrams point out whether the user‘s ‚own‘ school uses more or less energy than other schools or compare the energy use to the mean value.



Comparison of the monthly consumption of heating energy



Comparison of the annual consumption of heating energy

Indoor comfort in the classroom

This feature allows comparing measured indoor-air temperatures and characteristic values of carbon dioxide (CO_2) levels with the national requirements and acceptable ranges. The relevant measured data can be determined by a working group, for instance. In a graphical representation, the tool will then compare the data to the comfort requirements.

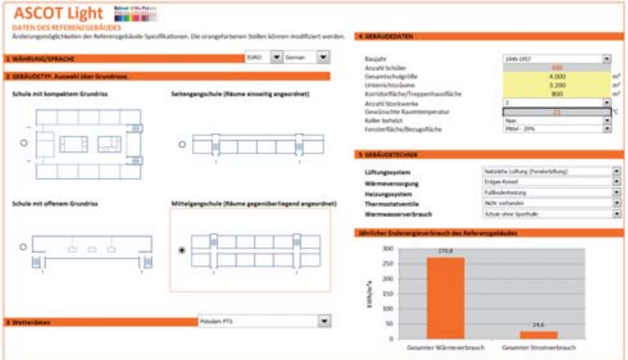
9 TRAINING OF PUPILS, TEACHERS AND TECHNICAL SERVICE PERSONNEL

To enhance the efficiency of the implemented renovation measures in the four demonstration projects and in further schools by raising user awareness and teaching correct user behaviour, tailored training materials for teachers, pupils and technical staff were developed (available in Danish, Norwegian, Italian, German, and English). The presentations describe the retrofit concepts and the specific implemented measures, give background information relating to saving energy in buildings and explain the influence of user behaviour on energy consumption and indoor comfort.

For this purpose, teachers are provided with teaching material for use in school lessons. The pupils learn how they can contribute to the successful retrofit of their school, and what they can do to further improve the indoor air quality and indoor air temperatures. Regarding the technical personnel, the focus is on enabling the staff to fully understand the new technologies and building control systems to ensure optimal use and maintenance.

In addition, a simplified version of the energy performance calculation tool 'ASCOT' was developed for the use in school lectures in the four languages of the 'School of the Future' partners. Based on typical examples of school building configurations, the young students will be able to evaluate different renovation measures in terms of energy performance and cost efficiency.

Having been tested at the four schools involved in the project, the training material was further improved and is now available for download at the project's website.



German version of the training tool 'ASCOT Light' for the simple assessment of renovation measures at school buildings

Training lesson at Hedegaards School

10 CONFERENCES, PUBLICATIONS, AWARDS

The project partners presented the project results at several distinguished national and international conferences (e.g. 'World Sustainable Energy Days', 'Nordic Passive House Conference', 'Central Europe towards Sustainable Buildings', 'Indoor Air Conference' and even at the 'ASHRAE Conference' in the USA). At two major conferences the partners organised entire conference sessions, presenting contributions related to 'School of the Future' and similar projects: at the 'International Conference on Solar Heating and Cooling 2013' and the 'International Conference on Building Physics for a Sustainable Built Environment 2015'.

Publications in specialized journals and conference proceedings, press releases, leaflets and videos completed the dissemination of project results. The project was presented in a broadcast by the German radio station Deutschlandradio including a statement by EU Commissioner Guenther Oettinger.

The demonstration projects won several awards: Brandengen School, for example, was awarded the 2014 Enova Prize 'Det Grønne Gullet' and received a prize awarded by the 'Local Climate Initiative 2012' of the association of Norwegian communities. Tito Maccio Plauto School was cited among top ten most significant examples of Italian Green Schools by Italian newspaper Corriere della Sera. Both the municipality of Cesena and Plauto School were presented in the scope of an Italian TV series. Visitors from all over the world (from China and Poland, for instance) came to see the renovated school buildings.

Award cermony of 'Det Grønne Gullet' prize (Photograph: Enova)

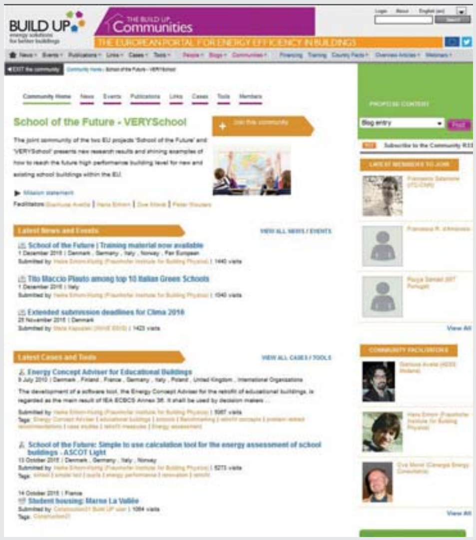
11 WEBSITE, PLATFORM FOR DISCUSSIONS, LINKS

All related results have been compiled on the project's website www.school-of-the-future.eu: the database on projects and programmes for energy-efficient schools, the technology screening reports, the retrofit guidelines, the information tool, the reports on planning and implementation of the demonstration projects, the sets of training material for the users and all publications.

At BUILD UP (www.buildup.eu), the European Commission's knowledge portal on energy-efficient buildings, the 'School of the Future' partners are moderating a discussion platform. This platform provides a forum for collecting and presenting news, events, case studies, calculation tools, publications and links related to energy-efficient school buildings. The outcome of 'School of the Future' can be retrieved there, just like many other results that were derived from numerous other national and international projects.

The project was conducted in direct communication with other national and international projects, to name but a few:

- EU IEE ZEMedS – Zero Energy Mediterranean Schools (www.zemeds.eu): The coordinators acted as technical advisers for the ZEMedS project
- EU CIP project VERYSchool (www.veryschool.eu): joint moderation of the BUILD UP discussion platform
- EU IEE project RenewSchool (www.renew-school.eu): Exchange on retrofitting technologies and costs
- BMWi-Forschungsschwerpunkt EnEff:Schule (www.eneff-schule.de): 'School of the Future' was presented several times at the national school congress organised by the German Research Initiative
- International Non-Profit Industrial association E2B (www.e2b-ei.eu): Input for presentations and annual updates of the project brochure
- The Research Centre on Zero Emission Buildings ZEB (www.zeb.no): Exchange with the coordinators of the Norwegian Research Centre



School of the Future discussion platform at www.buildup.eu

12 THE PROJECT PARTNERS

Fraunhofer IBP

ENEA
ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE

CENERGIA

STATENS BYGGEFORSKNINGSINSTITUT
AALBORG UNIVERSITET KØBENHAVN

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