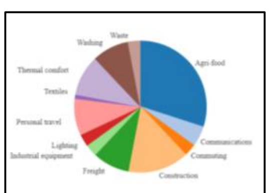
Low Carbon, High Comfort Integrated Lighting

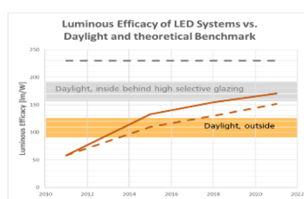
IEA SHC Task Definition Phase: **Status Report**

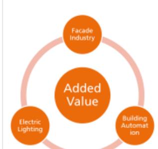
Jan de Boer, FHG-IBP, Stuttgart Germany
Eleanor Lee, LBNL Berkeley
Barbara Matusiak, NTNU, Norway
David Geisler-Moroder, Bartenbach, Austria
Niko Gentile, Lund University, Sweden
Jan Wienold, EPFL Switzerland
Victor Ferreira, IREC, Spain

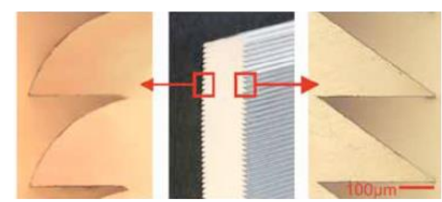
and all contributing experts

November 29, 2022







EBC Energy in Buildings and Communities Programme
SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

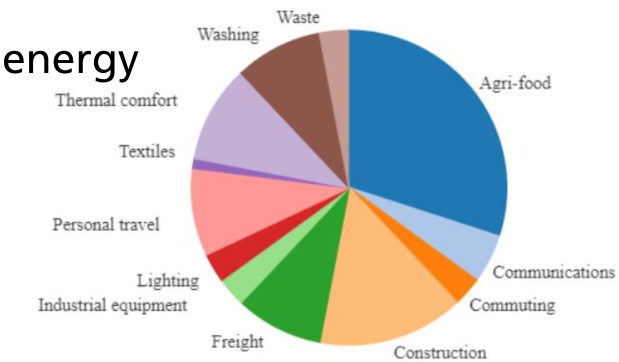
Lighting in context of decarbonization and energy efficiency

- Electricity for lighting accounts for 5% of the global greenhouse gas emissions and 15 % of the electrical energy consumption[1]

- More and more directly taxed CO_2 emissions, rising electricity prices, higher competition for electricity

- Widening the rating perspective of lighting solutions to a more holistic view of its impact on CO_2 emissions deemed necessary

Greenhouse gas emissions by service - 50.6Gt CO2e total [2]



Carbon Footprint of "Lighting value chain"

Product Stage → Planning /Design → Construction → Usage → End of Life Stage

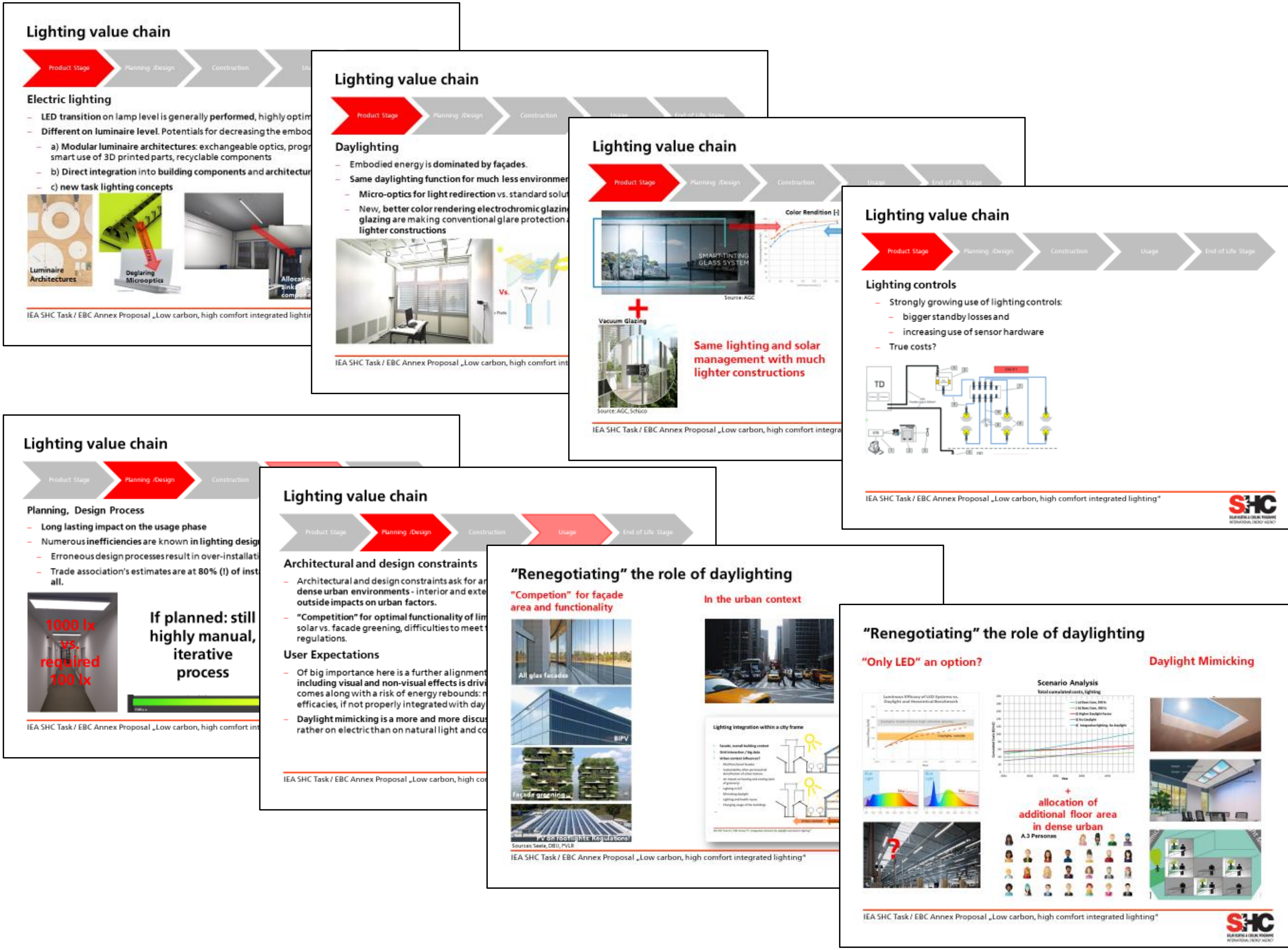
Digital Twin

Digitilization

IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort integrated lighting“

[1]UNEP Report, Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING, 2017
[2] https://public.tableau.com/app/profile/rosamund.pearce/viz/Greenhousegasemissionsbyservice/Dashboard1

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY


Lighting value chain
Product Stage
Planning /Design
Construction
Electric lighting
LED transition on lamp level is generally performed, highly optim
Different on luminaire level. Potentials for decreasing the embo
a) Modular luminaire architectures: exchangeable optics, progr
smart use of 3D printed parts, recyclable components
b) Direct integration into building components and architectur
c) new task lighting concepts
Luminaire Architectures
Deglaring Microoptics
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort integrated lightin
Lighting value chain
Product Stage
Planning /Design
Construction
Usage
End of Life Stage
Daylighting
Embodied energy is dominated by façades.
Same daylighting function for much less environmen
Micro-optics for light redirection vs. standard solu
New, better color rendering electrochromic glazin
glazing are making conventional glare protection
lighter constructions
Vs.
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort int
Lighting value chain
Product Stage
Planning /Design
Construction
Usage
End of Life Stage
Color Rendition [-]
SMART-TINTING GLASS SYSTEM
Source: AGC
Vacuum Glazing
Source: AGC, Schüco
Same lighting and solar management with much lighter constructions
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort integra
Lighting value chain
Product Stage
Planning /Design
Construction
Usage
End of Life Stage
Lighting controls
Strongly growing use of lighting controls:
bigger standby losses and
increasing use of sensor hardware
True costs?
TD
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort integrated lighting"
SHC
Lighting value chain
Product Stage
Planning /Design
Construction
Planning, Design Process
Long lasting impact on the usage phase
Numerous inefficiencies are known in lighting desig
Erroneous design processes result in over-installati
Trade association's estimates are at 80% (!) of inst
all.
1000 lx vs. required 100 lx
If planned: still highly manual, iterative process
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort in
Lighting value chain
Product Stage
Planning /Design
Construction
Usage
End of Life Stage
Architectural and design constraints
Architectural and design constraints ask for a
dense urban environments - interior and exte
outside impacts on urban factors.
"Competition" for optimal functionality of lim
solar vs. facade greening, difficulties to meet
regulations.
User Expectations
Of big importance here is a further alignment
including visual and non-visual effects is drivi
comes along with a risk of energy rebounds: n
efficacies, if not properly integrated with day
Daylight mimicking is a more and more discus
rather on electric than on natural light and co
IEA SHC Task / EBC Annex Proposal „Low carbon, high co
"Renegotiating" the role of daylighting
"Competion" for façade area and functionality
In the urban context
All glas facades
BIPV
Façade greening
PV on rooflights: Regulations
Lighting integration within a city frame
Sources: Seele, DBU, PVLR
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort integrated lighting"
"Renegotiating" the role of daylighting
"Only LED" an option?
Daylight Mimicking
Scenario Analysis
+ allocation of additional floor area in dense urban
?
IEA SHC Task / EBC Annex Proposal „Low carbon, high comfort integrated lighting"
SHC

Lighting Carbon footprint

Scenarios, strategies, roadmaps…

Solution 1

Product, Planning, Construction → Usage → End of Life Stage

Technology and design employed

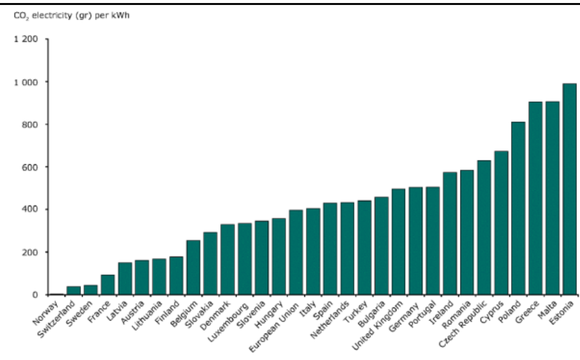
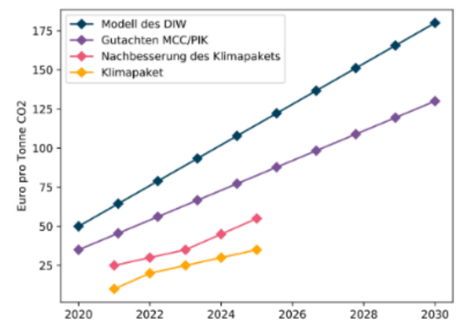


Figure 1: Production of CO2 to generate 1 kWh of electricity in the European Union



Supply side / grid context

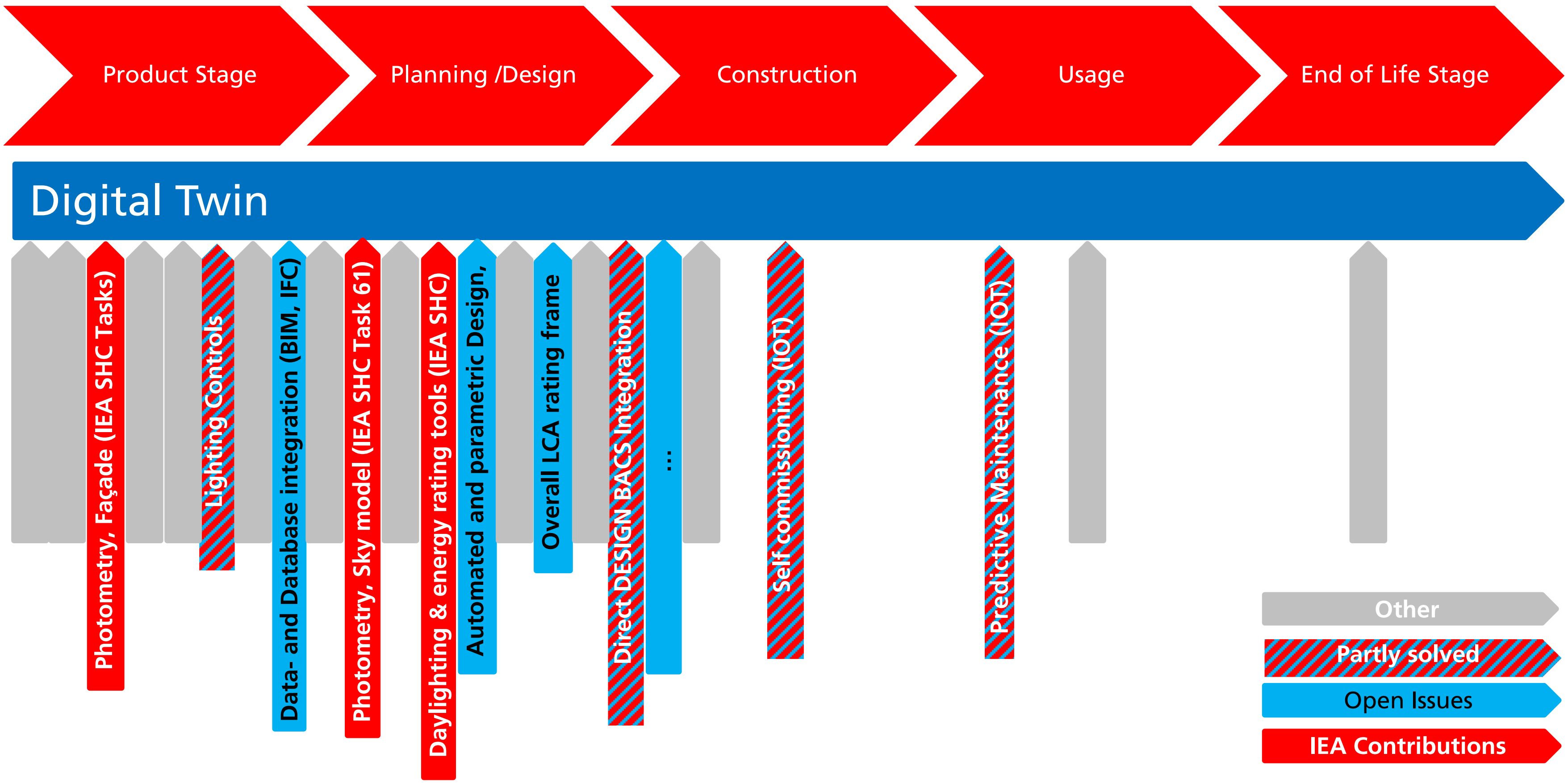
Solution x

Product, Planning, Construction → Usage → End of Life Stage

CO_2 eq. Kg per solution

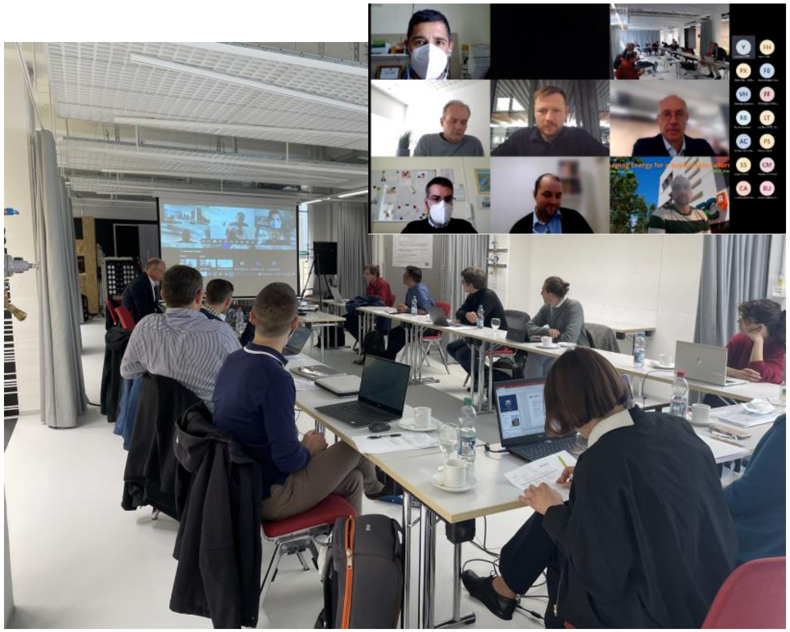
+ Link to other trades…

Empowering by digitalization



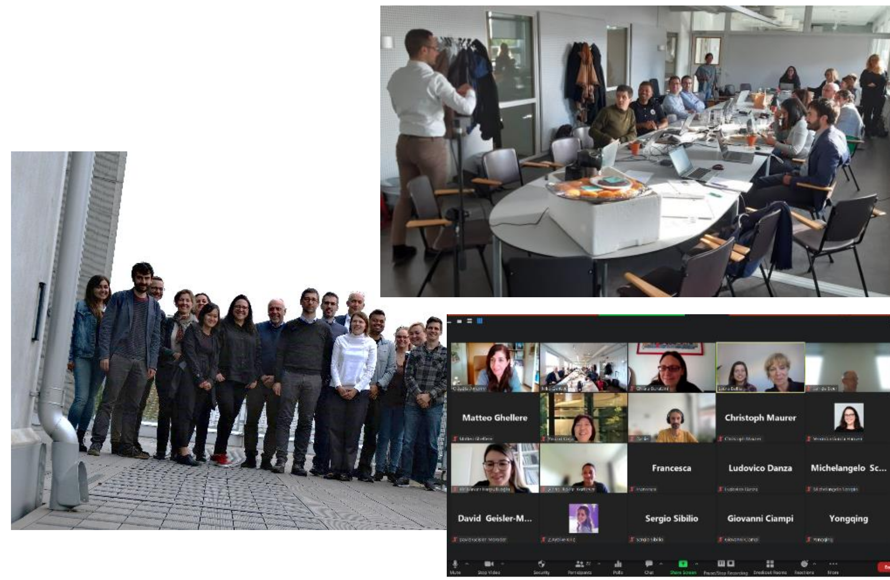
SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

2 Definition Workshops, Stuttgart (4/2022), Lund (10/2022)



47 participants from 17 countries

15 onsite, others online



49 participants from 19 countries

19 onsite, others online

Task Definition Coordination / Management

TDP coordination team

- Task organization: Jan de Boer, Fraunhofer Institute of Building Physics for PTJ, Germany

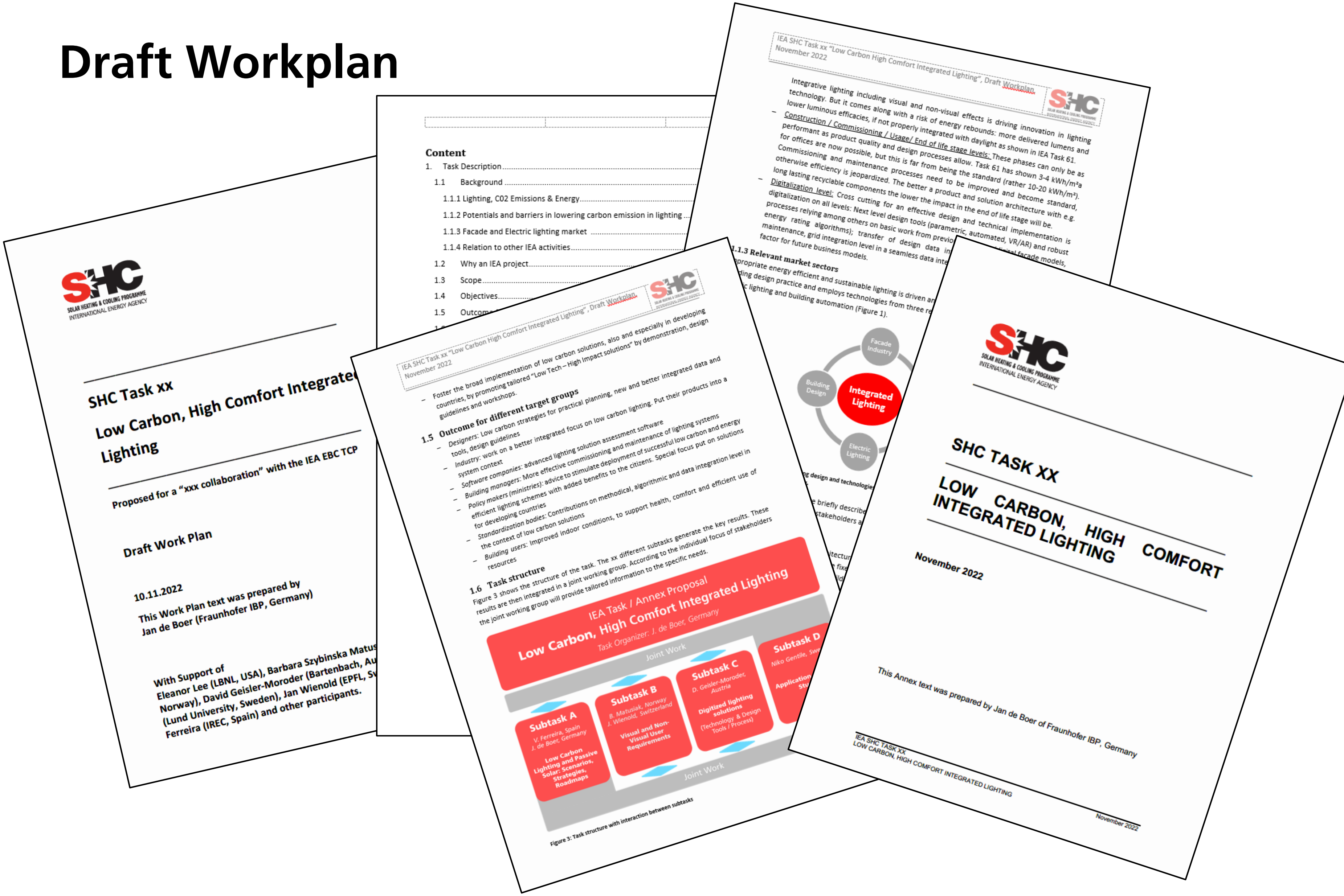
- Subtask development:
  - Barbara Matusiak, NTNU, Norway
  - Eleanor Lee, LBNL Berkeley
  - David Geisler-Moroder, Bartenbach, Austria
  - Niko Gentile, Lund University, Sweden
  - Jan Wienold, EPFL Switzerland
  - Victor Ferreira, IREC, Spain







Draft Workplan



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Objective

The overall objective of the activity is to identify and support implementing the potentials of lighting (electric, façade: daylighting & passive solar) in the decarbonisation on a global perspective, while aligning the new integrative understanding of humans' light needs with digitized lighting on a building and a building related urban scale.

Σ Overall Optimum serving the needs of users?

Product Stage | Planning /Design | Construction | Usage | End of Life Stage

Digital Twin **Towards a more seamless digital chain**

Proposed Structure

IEA Task / Annex Proposal

Low Carbon, High Comfort Integrated Lighting

Task Organizer: J. de Boer, Germany

Subtask A

V. Ferreira, Spain
J. de Boer, Germany

Low Carbon Lighting and Passive Solar: Scenarios, Strategies, Roadmaps

Subtask B

B. Matusiak, Norway
J. Wienold, Switzerland

Visual and Non-Visual User Requirements

Subtask C

D. Geisler-Moroder, Austria

Digitized lighting solutions

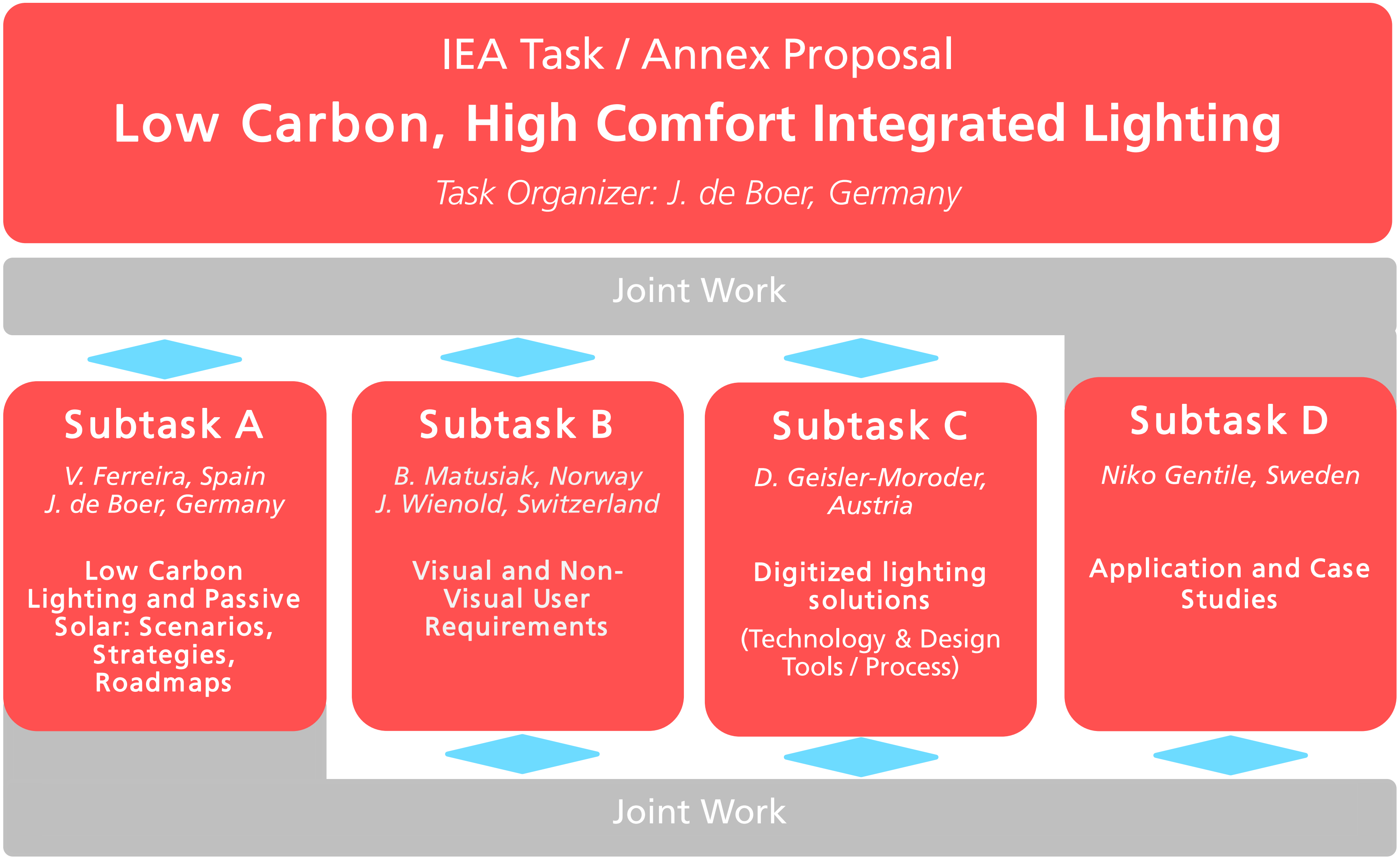
(Technology & Design Tools / Process)

Subtask D

Niko Gentile, Sweden

Application and Case Studies

Proposed Structure



Subtask A:
Low Carbon Lighting and Passive Solar: Scenarios, Strategies, Roadmaps

Coordination: Victor Ferreira, IREC, Spain with support of Jan de Boer, FHI-IBP, Germany

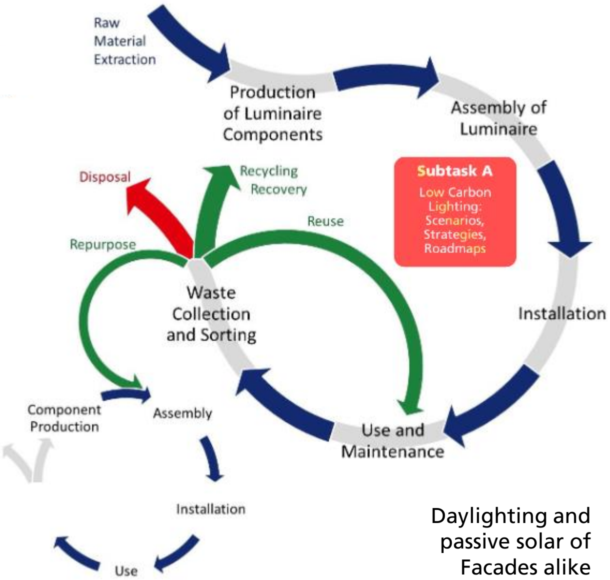
Objective: Based on existing first work on LCA for electric lighting (e.g. LEDs, luminaires) extend perspective to integrated lighting solutions including daylighting, facade systems, and controls. Set up of relevant scenarios (components, systems, local energy mixes, grid constraints, usage etc.). Evaluate with a tailored framework bringing together LCA / energy tools. From this parametric study develop "low carbon solution" strategies by intelligently combining new technical components and design concepts: Identify low hanging fruits, Illustrate the impact of no/bad/good design. Address business models in this context.

A.1. Status quo: Overview on data, methods, regulations

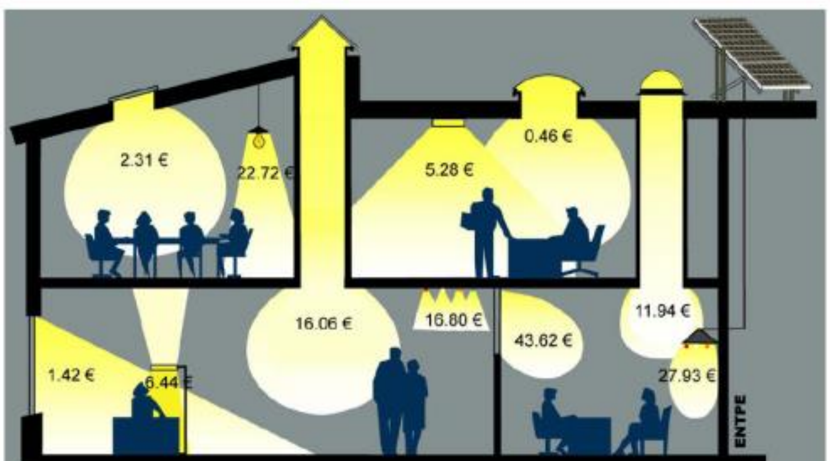
A.2. Catalogues of Scenarios

A.3. Framework for flexibly rating different scenarios

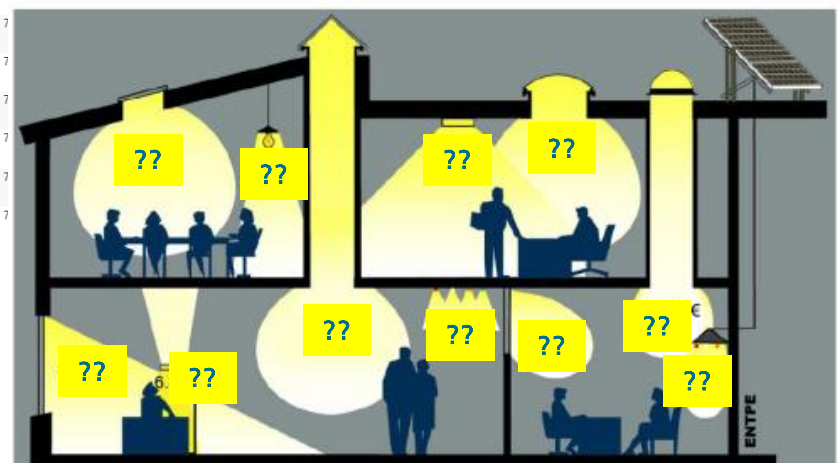
A.4. Design Guide, Strategies and Roadmaps



Daylighting and passive solar of Facades alike



Annual costs (€/Mlmh) for various lighting and daylighting techniques, Source: Marc Fontoynont



Carbon Footprint (e.g. $kgCO_2eq/Mlmh$) for various lighting and daylighting techniques

Subtask B:
Visual and non-visual User Requirements

Coordination: Barbara Matusiak, NTNU, Norway and Jan Wienold, EPFL, Switzerland

Objective: Daylighting and lighting design is moving from a "photometric" or "visual" to a "spectral" definition of lighting quality including "non-visual" effects. Focus on understanding how lighting and daylighting schemes can address both – often contrasting - visual and non-visual requirements in an effective, resource efficient way, taking the built environment but also the surrounding in the big picture by means like intervention studies.

B.1. Improved understanding of visual discomfort for humans

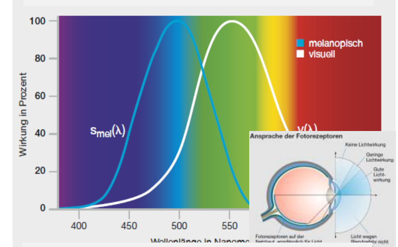
B.2. View preferences/descriptors for rooms with different visual stimuli and activities

B.3. Relation between the view out of the window and urban morphology

B.4. New developments for non-visual aspects

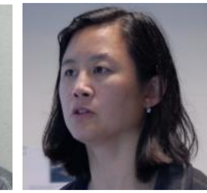
B.5. Measurements and assessment methods of non-visual aspects

Spectral Sensitivity Curves



Circadian illumination in offices

Subtask C:
Digitized lighting solutions (Technology & Design Tools / Process)

Coordination: David Geisler-Moroder, Bartenbach, Austria with support of Eleanor Lee, LBNL, U.S.A

Objective: Evaluate and contribute to the digitization of lighting which is taking place at the **technology** and the **design process** level in its impact on a low carbon footprint

Technology: Review the state-of-the-art practice for digital component integration via the internet of things (IOT), as well as benefits for commissioning and maintenance of lighting installations

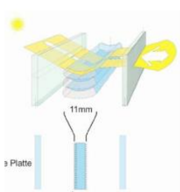
C.1. System concepts for digitalized lighting solutions and combined daylight and solar utilization

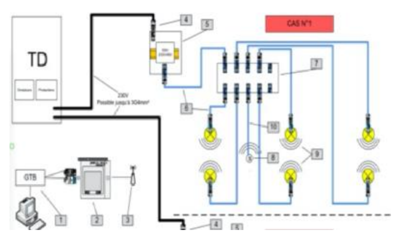
C.2. IOT and control systems

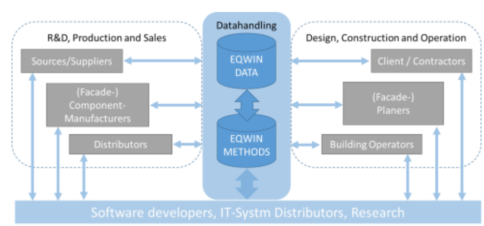
Design Tools / Process: Focus on the integration of lighting in the overall BIM workflow analyzing the current status. Design software will be evaluated regarding seamless data and workflows (connecting to BMS, “Human Lighting Interface”, etc.), parametric and automated design options to better understand carbon impacts given temporal availability of clean energy, certification and code compliance calculations, and advanced communication options.

C.3. BIM - continuous workflow for integrated lighting solutions and underlying data

C.4. Simulation methods for integrative lighting design and VR possibilities







Subtask D:

Application and Case Studies

Coordination: Niko Gentile, Lund University, Sweden

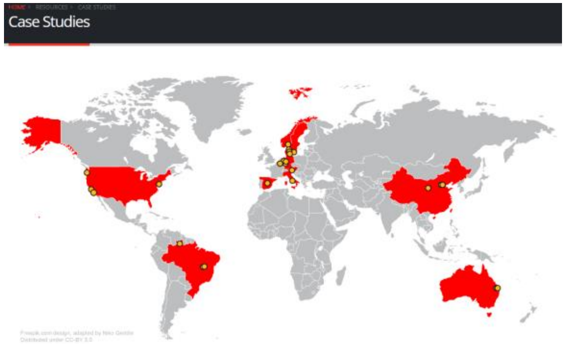
Objective: Collect experiences from applications and case studies, with a focus on the environmental impact of their whole life cycle. And communicate opportunities and challenges to stakeholders wishing to build or retrofit daylighting and lighting in the least environmentally impactful way, while keeping the lighting quality high.

D.1. Catalogue of case studies

D.2. Evaluation procedure

D.3. Data collection and analysis

D.4. Lessons learned

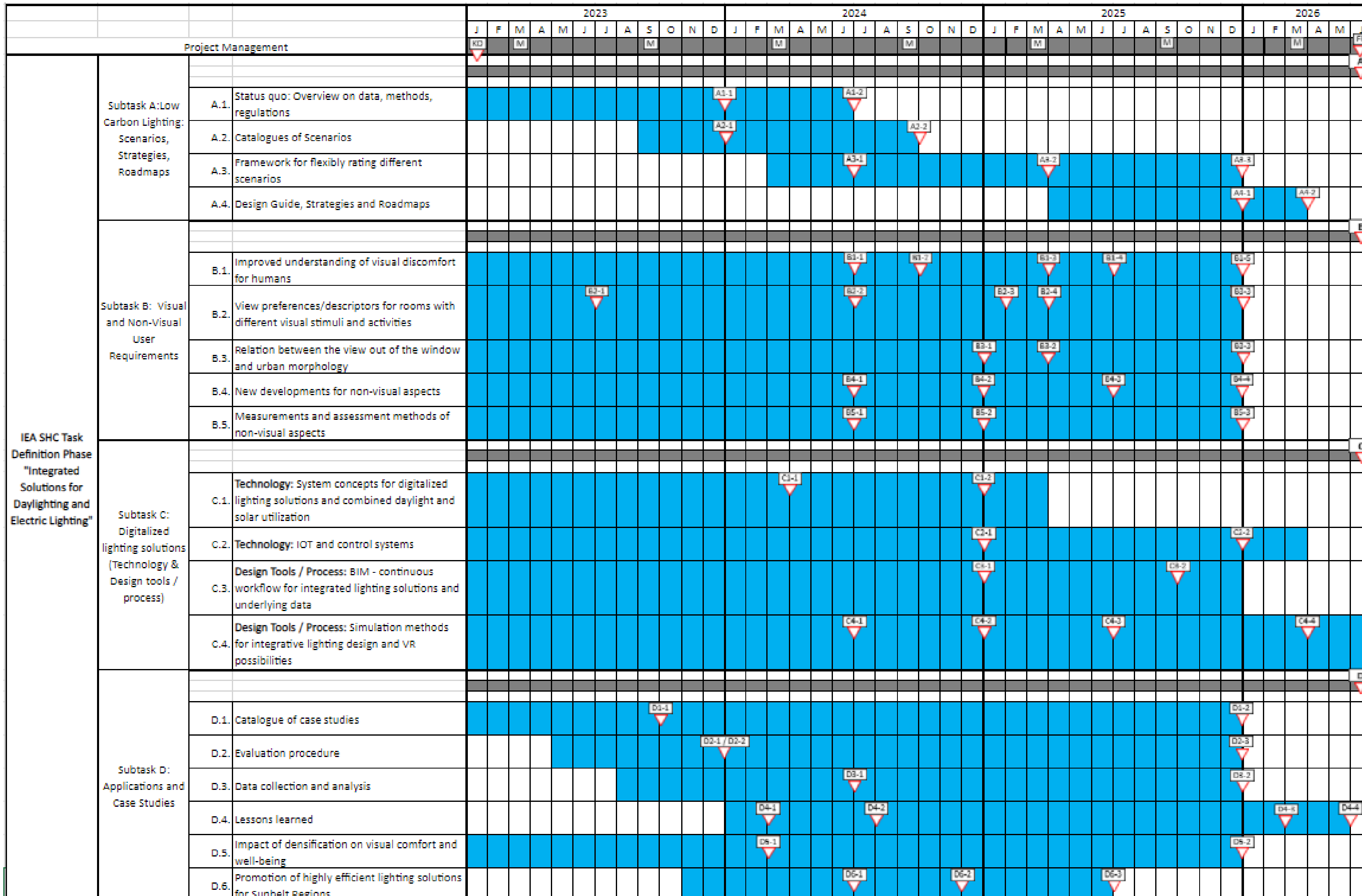


D.5. Impact of densification on visual comfort, well-being, and rescources used

D.6. Promotion of highly efficient lighting solutions for Sunbelt Regions, GN-SEC

CCREEE RCREEE
EACREEE SACREEE
ECREEE SICREEE

Milestones


2023
2024
2025
2026
Project Management
Subtask A:Low Carbon Lighting: Scenarios, Strategies, Roadmaps
A.1. Status quo: Overview on data, methods, regulations
A.2. Catalogues of Scenarios
A.3. Framework for flexibly rating different scenarios
A.4. Design Guide, Strategies and Roadmaps
Subtask B: Visual and Non-Visual User Requirements
B.1. Improved understanding of visual discomfort for humans
B.2. View preferences/descriptors for rooms with different visual stimuli and activities
B.3. Relation between the view out of the window and urban morphology
B.4. New developments for non-visual aspects
B.5. Measurements and assessment methods of non-visual aspects
IEA SHC Task Definition Phase "Integrated Solutions for Daylighting and Electric Lighting"
Subtask C: Digitalized lighting solutions (Technology & Design tools / process)
C.1. Technology: System concepts for digitalized lighting solutions and combined daylight and solar utilization
C.2. Technology: IOT and control systems
C.3. Design Tools / Process: BIM - continuous workflow for integrated lighting solutions and underlying data
C.4. Design Tools / Process: Simulation methods for integrative lighting design and VR possibilities
Subtask D: Applications and Case Studies
D.1. Catalogue of case studies
D.2. Evaluation procedure
D.3. Data collection and analysis
D.4. Lessons learned
D.5. Impact of densification on visual comfort and well-being
D.6. Promotion of highly efficient lighting solutions for Sunbelt Regions

Joint Work

Main aspects of work integration between the 4 subtasks

Overview on subtask joint activities and possible overlaps, 8.11.2022

	A.1 Status quo: Overview on data, methods, regulations	A.2 Catalogues of Scenarios	A.3 Framework for flexibly rating different scenarios	A.4 Design Guide, Strategies and Roadmapsy	B.1 New developments for visual aspects	B.2 ew developments for non-visual aspects	B.3 Relation between the view out of the window and urban morphology	B.4 New developments for non-visual aspects	B.5 Measurements and assessment methods of non-visual aspects	C.1 System concepts for digitalized lighting solutions	C.2 Daylight and solar utilization in facade and roof	C.3 IOT	C.4 BIM - continuous workflow for integrated lighting solution	D.1 Catalogue of case studies	D.2 Evaluation Procedure	D.3 Data collection and analysis	D.4 Lessons learned	D.5 Impact of densification on visual comfort	D.6 Promotion of highly efficient solutions for sunbelt regions
A.1 Status quo: Overview on data, methods, regulations																			
A.2 Catalogues of Scenarios																			
A.3 Framework for flexibly rating different scenarios																			
A.4 Design Guide, Strategies and Roadmaps																			
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B.5 Measurements and assessment methods of non-visual aspects																			
C.1 System concepts for digitalized lighting solutions and combined daylight and solar utilization																			
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D.1 Catalogue of case studies																			
D.2 Evaluation Procedure																			
D.3 Data collection and analysis																			
D.4 Lessons learned																			
D.5 Impact of densification on visual comfort																			
D.6 Promotion of highly efficient solutions for sunbelt regions																			

Joint activities, please specify, in which Subtask the results will be documented

Interaction between activities, please specify who is expecting what

Possibly overlapping activities, please make proposal to resolve

Relation to ongoing or previous SHC Tasks, EBC Annexes and other Programs

Solar Resources

PVPS Task 16: Solar Resource for High Penetration and Large Scale Applications

Digitization

IEA EBC Annex 81: Data-Driven Smart Buildings

User Aspects

EBC-Annex 79 „Occupant-Centric Building Design and Operation“ as successor of Annex 66

EBC Annex 87: “Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems”

Lighting

- IEA-SHC Task 21/ECBCS Annex 29 „Daylighting in Buildings“
- IEA-SHC Task 31 „Daylighting Buildings in the 21st Century
- IEA Task 56 „Building Integrated Solar Envelope Systems “
- IEA-ECBCS Annex 45 „Energy Efficient Electric Lighting for Buildings“
- 4E Solid State Lighting Annex
- IEA-SHC Task 50 “Advanced Lighting Solutions for retrofitting Buildings”
- **IEA SHC Task 61/Annex 77 „Integrated Solutions for Daylighting and Electric Lighting“**

Low carbon, high comfort integrated lighting

Standardization

CIE TC 3-59 on spectral design of lighting;

JTC 06 (CIE-ISO) on energy performance

CEN TC 169 and ISO TC 274

Expressed Interest: Research

Country	Organisation	Interest in Subtask			
		A	B	C	D
Australia	Queensland University of Technology		X		X
Austria	Bartenbach	X	(X)	X	
	HELLA	X		X	
Belgium	Université catholique de Louvain		X	X	X
Brazil	Universidade de Brasília		X	(X)	X
Canada	University of Toronto			X	
China	Beijing University of Technology	X	X		
	China Academy of Building Research	X	X		X
	Soochow University	t.b.d.			
Denmark	DTU Civil Engineering		(X)	X	X
Germany	Fraunhofer-Institut für Bauphysik	X		X	(X)
	Fraunhofer-Institut für Solare Energiesysteme			X	
	Priedemann Fassadenberatung GmbH			X	X
Italy	Construction Technology Institute (ITC-CNR)		X		(X)
	Sapienza Università di Roma		(X)		X
	University of Campania		X	X	(X)
	University of Naples Federico II		X	X	
Japan	Kyushu University		(X)	X	
Norway	NTNU		X		
Poland	Gdansk University of Technology		X	(X)	X
Spain	IREC – Fundació Institut de Recerca en Energia de Catalunya	X	(X)	(X)	(X)
Sweden	Lund University		X		X
Switzerland	Empa - Swiss Federal Laboratories for Materials Science and Technology	X		X	(X)
	EPFL		X		X
	Idiap Research Institute			X	(X)
	Lucerne University of Applied Sciences and Arts	(X)	X	X	
Türkiye	University of Instanbul	X	X		X
United Kingdom	University of Cambridge		X		X
U.S.A.	Lawrence Berkeley National Laboratory			X	(X)
	Oregon State University		X		

Since Workplan submittal: Netherlands, TU-Delft

Expressed Interest: Industry

Country	Company	Short name /Abbreviation
Austria	Hella, Sunshading	HEL
	Bartenbach	BL
Denmark	Velux	VEL
China	t.b.d. Luo Tao is contacting companies	
Germany	Different trade associations (electric lighting and façade)	TA
	Interpane	IP
	Priedemann Façade Lab	PFL
Norway	Norconsult	NoC

Task # Information Plan

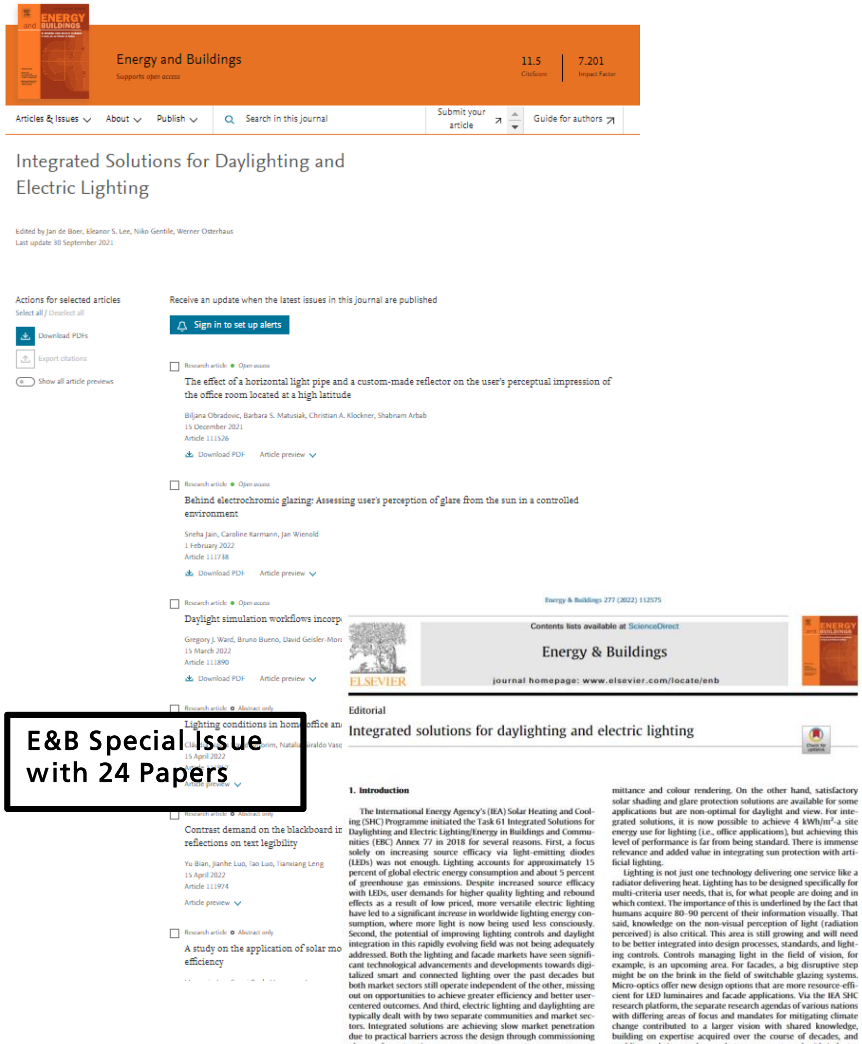
Task Duration:

Target Audience

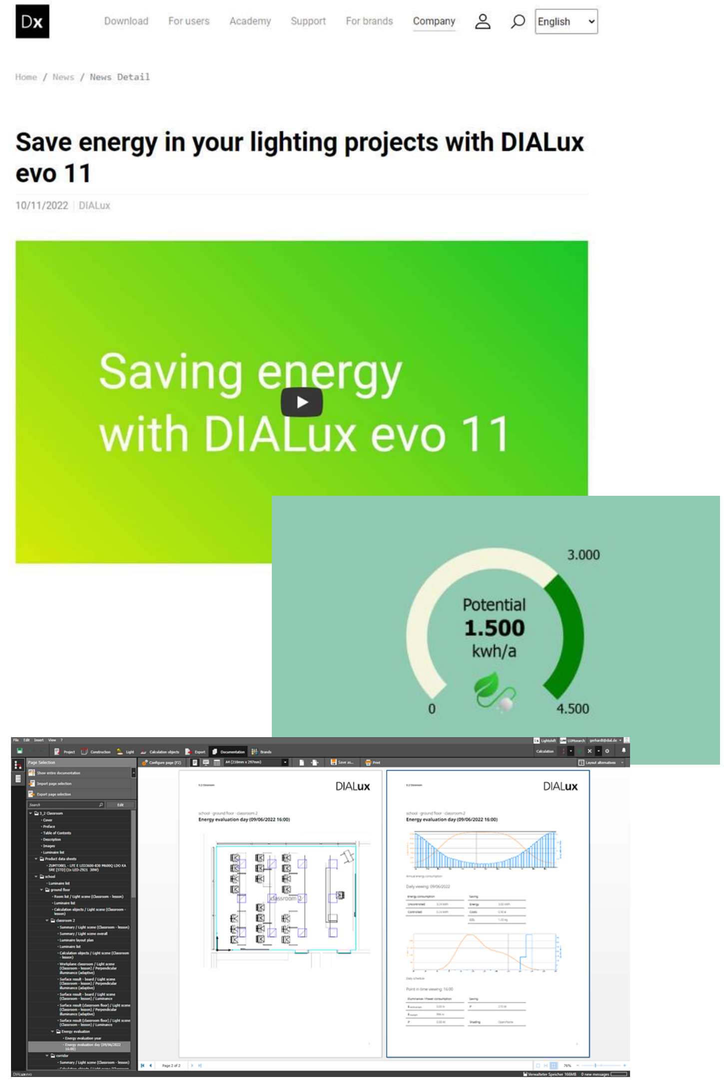
Subtask	Policy makers	R&D scientists	Architects, Lighting Designers	Industry (Lighting, Facade, BMS)	Standardization bodies	XREEE Centers	SHC ExCo	#	Title/Proposed Title	Format	Task Month
Subtask A								A1	Survey on data sources, methods and regulations	Internal document (not public)	12
								A2	Catalogue of scenarios	Internal document (not public)	21
	X		X	X				A3	Simple tool to rate LCA / GWP	SHC website	36
			X					A4	Design guideline	SHC website	36
	X			X				A5	Roadmap	SHC website	39
	X		X	X				A6	Report "Low Carbon Lighting: Scenarios, Strategies and Roadmaps"	SHC website	42
Subtask B								B1	Documentation B.1-B.5 as working documents	Internal documents (not public)	36
		X	X	X	X			B2	Information material on "New developments for non-visual aspects" as report or short video	SHC website	36
		X	X	X	X			B3	Report "Visual and Non-Visual User Requirements"	SHC website	42
Subtask C								C1	Documentation C.1-C.4 as working documents	Internal documents (not public)	36
		X	X	X				C2	Refactored Radiance core tools	Software via SHC Website	30
		X	X	X				C3	White paper on current state-of-the-art of lighting simulation software tools for visual and non-visual performance evaluation.	White Paper (Public)	36
	X	X	X	X				C4	Report "Digitalized Lighting Solutions for low carbon build environments – Status quo and outlook"	SHC website	42
Subtask D								D1	Documentations D.1-D.5 as working documents	Internal document (not public)	36
	X	X	X		X			D2	Information material about D.5 "Impact of densification on visual comfort and well-being" as report or short video	SHC website	36
		X	X	X				D3	Report "Low carbon daylighting and lighting solutions: practical applications"	SHC website	42
TCP/Other	X	X	X	X	X				Task webpage	SHC website	2
	X	X	X	X	X				Task brochure (optional)	SHC website and Print	2
	X	X	X	X	X		X		TCP Annual Report contribution (1 per year)		annually
	X	X	X	X	X				Task Highlight report (1 per year)		annually
	X		X	X					Position Paper (ExCo needs to approve request to omit)		42
	X	X	X	X					Solar Update articles (minimum during and end)		24/42
							X		Task Status report (2 per year)		twice per year
							X		Final Management report		42
							X		Mid-term Task evaluation		21
							X		Final Task evaluation		42
	X	X	X	X					Solar Academy webinar	Workshop	30
						X			"Low Tech, High Impact" Lighting solution for sunbelt regions	Workshop	30
		X	X	X					Special journal issue for scientific papers	Wiley or Elsevier or other	42
	X		X	X		X			Industry Workshops each face to face task meeting	Workshop	twice per year

*A Task report is an official document of the Task that is approved by the Task Publication Committee. They do not include conference papers and presentations.

Addendum to *IEA SHC Task 61 / EBC Annex 77*



E&B Special Issue with 24 Papers



Technology Position Paper

Integrated Day- and Electric Lighting in Non-residential Buildings

November 2022

Challenge	Action needed
Harvest 'low hanging fruit' in electric lighting	• Replace old lighting installations with **LED** technology. • Request **luminaire efficiencies >150 lm/W.** • Refocus from decisions based on pure investment costs to **total cost of ownership.**

Strengthen the role of daylighting	• **Recognize daylight** – which nowadays can be sufficiently quantified as a substitute for electric lighting – **a "renewable energy source"** – allowing for **inclusion in subsidy programs** as known from other market sectors (PV, wind, etc.).
	• **Use sustainability certificates** to promote daylighting, if not included, or revisit existing certificates and update.
	• Demand **a minimal window to floor area ratio,** e.g., in central Europe between **1/8 and 1/10**.
	• **Revise ordinances** to demand technical and economical advantageous daylighting solutions, such as:
	  - **Daylight-supportive combinations of glazing and sun shading/glare protection** devices
	  - **Light redirecting** fenestration, and
	  - Daylight and occupancy sensitive **electric lighting controls** also integrated with facades (i.e., visual comfort driven when occupied, solar gain driven when unoccupied).

Widen the rating perspective of lighting	• Put lighting into the perspective of its **impact on decarbonization**. • **Foster LCA approaches** for rating integrated lighting.
Rethink products	• Make **product architectures**[5] more **sustainable.** • Push product design based on **micro-optics** for LED luminaires and façades applications. • Support development and implementation of disruptive façade technologies like **switchable glazing systems,** ideally **in combination with vacuum glazing,** to drastically lower a façade's embodied energy.
Improve Design Processes	• Make **planning** of lighting installations **mandatory.** Foster **employment of new available integrated design and rating tools**, which in part automatically indicates not yet allocated potentials. • Introduce processes **ensuring** certain **daylight quality levels** (e.g., parametric, automated design tools. • Use **design strategies** that prompt **energy efficient behaviors**. • Support the **deployment** of concepts from **new daylighting and electric lighting standard** (e.g., EN

[5] Product architecture is the organization (or chunking) of a product's functional elements.

Organisational Matters / Issues for the EXCO

- Planned duration 3,5 years: 1/2023-6/2026

- Participation of your experts greatly appreciated

- Kick-off planned: 17^{th}-19^{th} of April 2023, Aversa, Italy

- Collaboration with EBC:
  - Istanbul EXCO meeting: Committment for collaboration, Level still open
  - Interested to join via EBC: Brasil, Italy, Japan, Sweden, USA.
  - Liason officer („Annex Adviser“)