ARUP

Life Cycle Assessment – CERN Linear Colliders

Comparative Carbon Footprint of Underground Civil Engineering Facilities for Future Colliders

13/01/2023

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LCA – CERN Linear Colliders

Agenda

- Programme
- A1-A3 LCA
  - Scope and approach
  - Desk study review
  - Modelling assumptions and queries
- A4-A5 LCA
- Tools workflow and visualisation
- Next steps, questions/discussion/AOB

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Programme

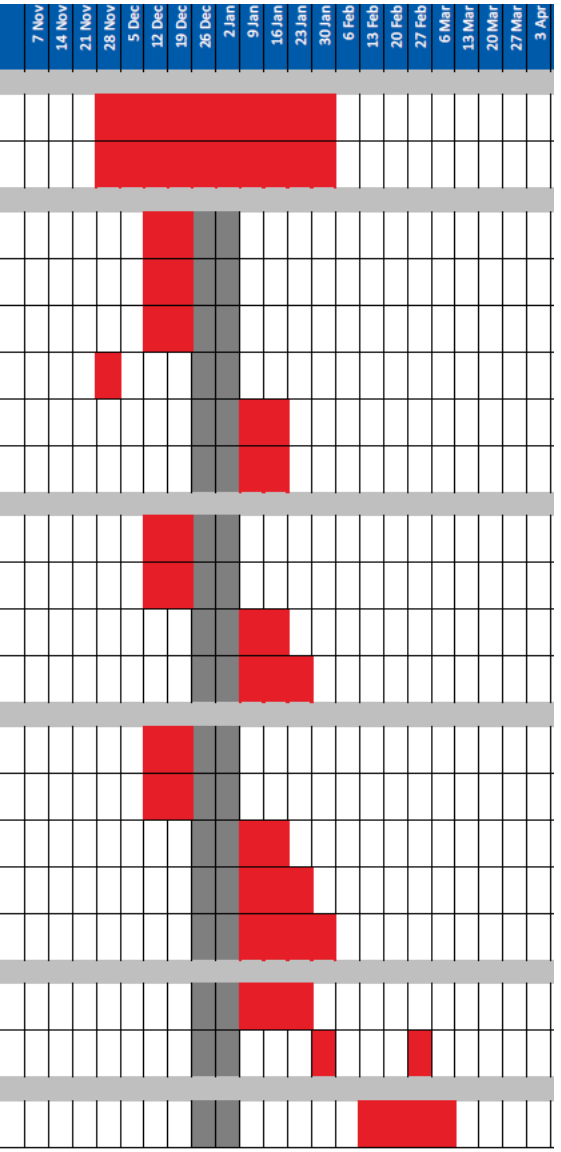
Phase 1

Stage 1
Desk Study /
Design Intent Clarification

Stage 2
LCA (A1-A3) CLIC
LCA (A1-A3) ILC

Stage 3
Future Considerations

Task Ref	Task Type	Task	Start Date (w/c date)
1	Main	*Project Management/mtgs*	
1.01	Sub	Internal & CERN mtgs (1/2 progress meetings with CERN as required)	28 Nov 22
1.02	Sub	Project management tasks; management of resources, programming, cost control etc	28 Nov 22
2	Main	*Stage 1 - Desk study and design intent clarification*	
2.01	Sub	Desk study and data review of CLIC drive beam and klystron tunnel, Geneva	12 Dec 22
2.02	Sub	Desk study and data review of ILC tunnel, Japan	12 Dec 22
2.03	Sub	Review Rodríguz and Pérez and other relevant methodology	12 Dec 22
2.04	Sub	Choose life cycle assessment tools	28 Nov 22
2.05	Sub	Design intent and clarification CLIC options	09 Jan 23
2.06	Sub	Design intent and clarification ILC option	09 Jan 23
3	Main	*Stage 2 - LCA CLIC, Geneva*	
3.01	Sub	Receive and review tunnel cross sections/BIM model, materials information	12 Dec 22
3.02	Sub	If available, receive and review transport distances of construction materials, construction methods, materials/energy suppliers during construciton/MEP products	12 Dec 22
3.03	Sub	Parametric modelling of 4 CLIC tunnel options (3 CLIC Drive Beam of 380GeV 1.5TeV 3Tev, 1 CLIC Klystron 380GeV) to allow designs to be easily recalculated	09 Jan 23
3.04	Sub	Undertake A1-A3 assessment (Raw material supply, transport, and manufacture of materials)	09 Jan 23
4	Main	*Stage 2 - LCA ILC, Japan*	
4.01	Sub	Receive and review tunnel cross sections/BIM model, materials information	12 Dec 22
4.02	Sub	If available, receive and review transport distances of construction materials, construction methods, materials/energy suppliers during construciton/MEP products	12 Dec 22
4.03	Sub	Parametric modelling of 1 ILC tunnel option (250GeV) to allow designs to be easily recalculated	09 Jan 23
4.04	Sub	Undertake A1-A3 assessment (Raw material supply, transport, and manufacture of materials)	09 Jan 23
4.05	Sub	Coordination with Arup Japan / KEK	09 Jan 23
5	Main	*Stage 3 - Future considerations research*	
5.01	Sub	Identify probable trends in materials and influence on costs based on known carbon pricing mechanisms between 2022 and 2040	09 Jan 23
5.02	Sub	1/2 future considerations CERN workshops. (wider net zero targets, tools to compare and minimise environmental impacts on existing and future assets.) Dates indicative and TBC	Dates TBC
6	Main	*Deliverables*	
6.01	Sub	Interim report outlining LCA methodology and A1-A3 comparison between the 3 proposed linear collider options and the 3 CLIC Drive Beam energies (by March 2023)	13 Feb 23



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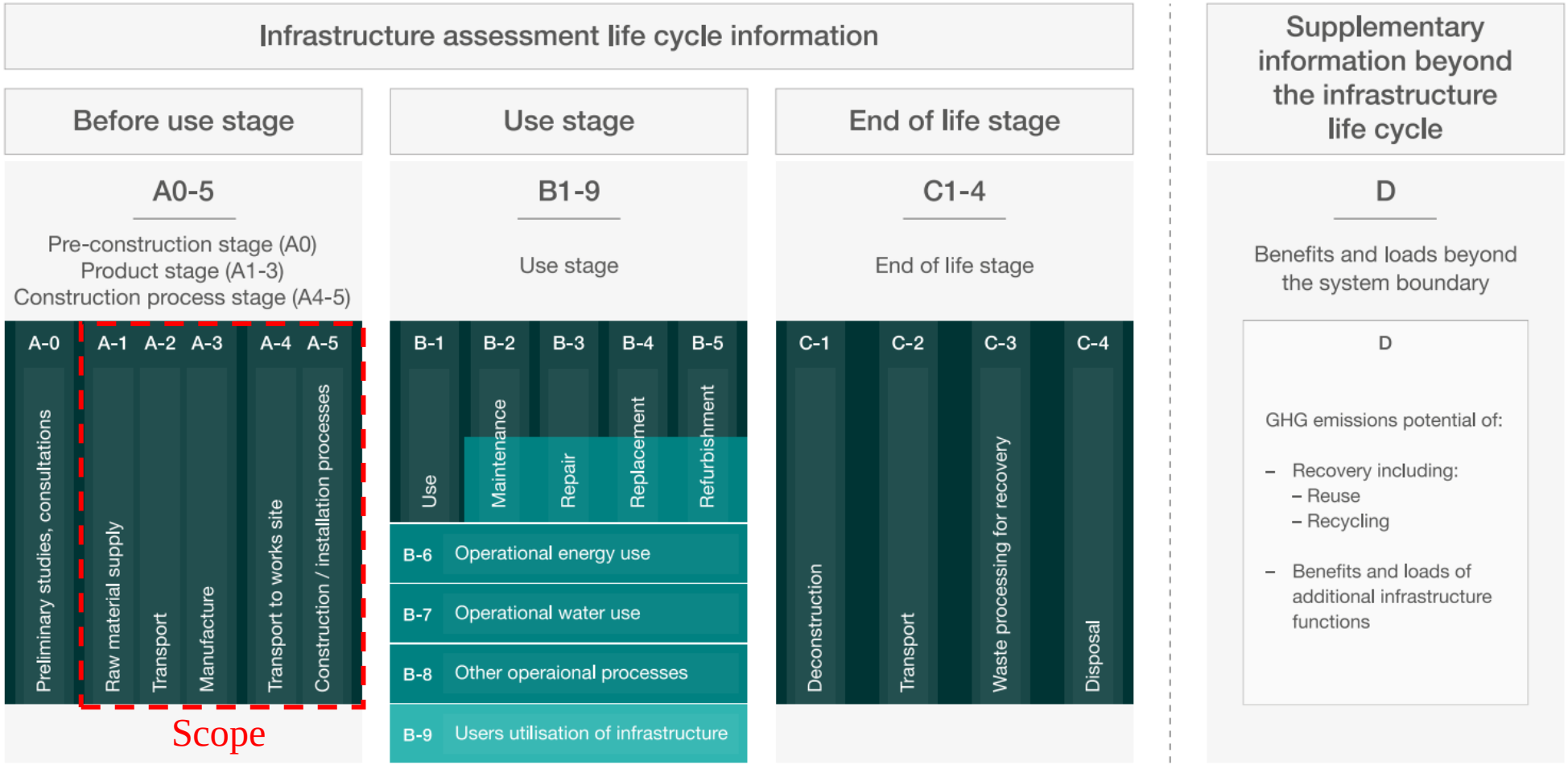
Scope

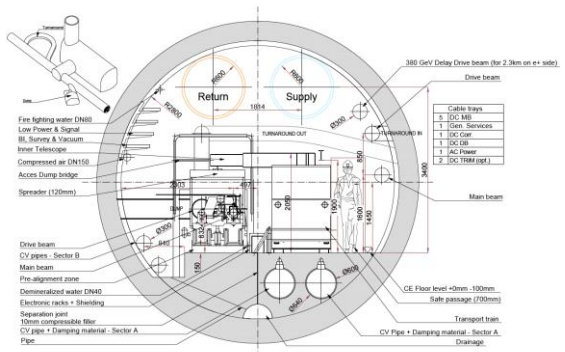
Embodied and construction emissions (A1-A5)



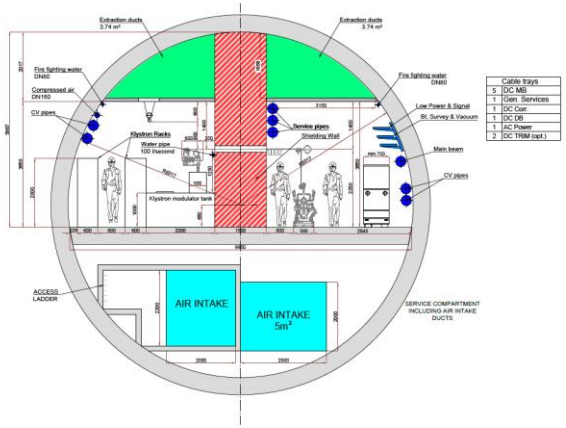
Ref: PAS2080

Approach to A1-A5

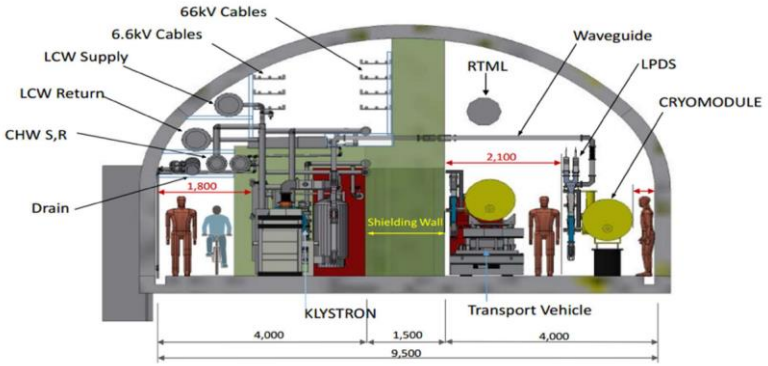
1. CLIC Drive Beam tunnel
5.6m internal dia. Geneva.
(380GeV, 1.5TeV, 3TeV)



2. CLIC Klystron tunnel
10m internal dia. Geneva.
(380GeV)



3. ILC tunnel
Arched 9.5m span. Japan.
(250GeV)



Methodology: ISO 14040/44

Database: TBC

Functional unit: tCO2e/m tunnel length

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Desk Study

References:

- Rodriguez, R., Perez, F., 2021. Carbon foot print evaluation in tunnelling construction using conventional methods.
- Huang, L. Bohne, R., Bruland, A., Drevland, P., Lohne, J., 2015. Environmental impact of drill and blast tunnelling: life cycle assessment. In: Journal of Cleaner Production. Vol.86. 2015
- Li.Q, 2013. CO emissions during the construction of a large diameter tunnel with a slurry shield TBM . World Tunnel Congress 2013 Geneva.
- Huang, L. Bohne, R., Bruland, A., Drevland, P., Salomonsen, A., 2013. Life Cycle Assessment of Norwegian standard road tunnel. In: The 6th International Conference on Life Cycle Management in Gothenburg 2013.
- Li.Q, 2015. Study of influential factors and measures for low carbonization during the construction of shields tunnels. Vol.86. 2015
- Ahn C.B., Xie H., Lee S.H. 2010. Carbon footprints analysis for Tunnel Construction Processes in the Preplanning Phase using Collaborative Simulation. Construction Research Congress, Alberta, 1538-1546, American Society of Civil Engineers. Reston.

Desk Study

Impact Categories

	Environmental Impact Categories									
	Core Categories (BS EN 15804:2012+A2:2019)						Additional Categories (BS EN 15804:2012+A2:2019) and ReCiPe			
	Global warming potential (GWP)	Ozone Depletion Potential (ODP)	Eutrophication Potential (EP)	Acidification Potential (AP)	Photochemical Ozone Creation Potential (POCP)	Abiotic Depletion Potential (ADP)	Particulate Matter (PM)	Human Toxicity Potential (HTP)	Ionising Radiation Potential (IRP)	Ecotoxicity (ETP)
Rodriguez, R., Perez, F. (2021)	X									
Huang, L. (2014)	X			X	X		X	X		X
Li, Q et al. (2013)	X									
Huang, L. (2013)	X	X	X	X	X		X	X	X	X
Li, Q. (2015)	X									
Ahn, C.B. (2010)	X						X			

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Desk Study

Summary of Papers

Paper	Excavation Method	A1-A3	A4-A5	Further breakdown
Rodriguez, R., Perez, F. (2021)	D&B	85%	15%	Materials (80% concrete, 5% steel), loading and transportation (5%), generating electricity (10%)
Huang, L. (2014)	D&B		100% (A5 only)	D&B (29%), loading & hauling (36%), ventilation (31%)
Li, Q et al. (2013)	TBM	89.18% (A3 only)	10.82% (A5 only)	Precast of segment (27.79%), shield driving (33.71%), segment erection (27.1%), tunnel inner structures construction (6.68%) and auxiliary (4.72%)
Huang, L. (2013)	D&B	57%	43%	Materials (57%), diesel use for construction machine (16%), electricity (16%), transportation of materials (11%)
Li, Q. (2015)	TBM	-	-	
Ahn, C.B. (2010)	TBM	-	35% (A5 TBM)	

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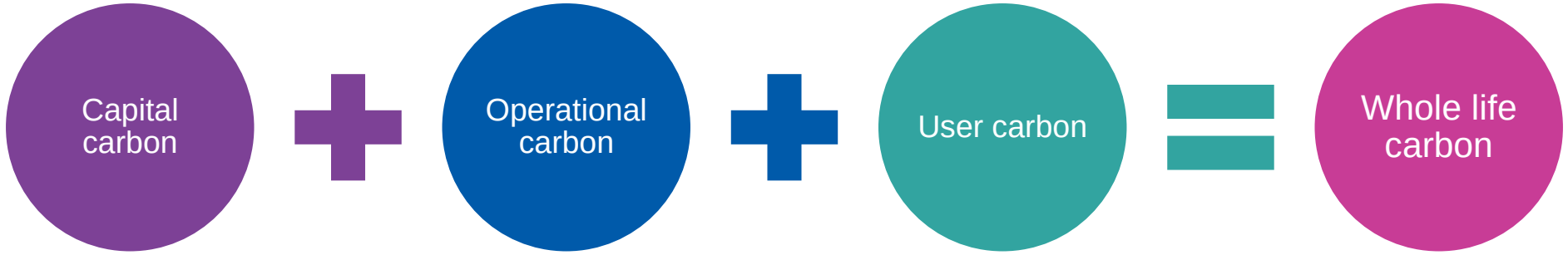
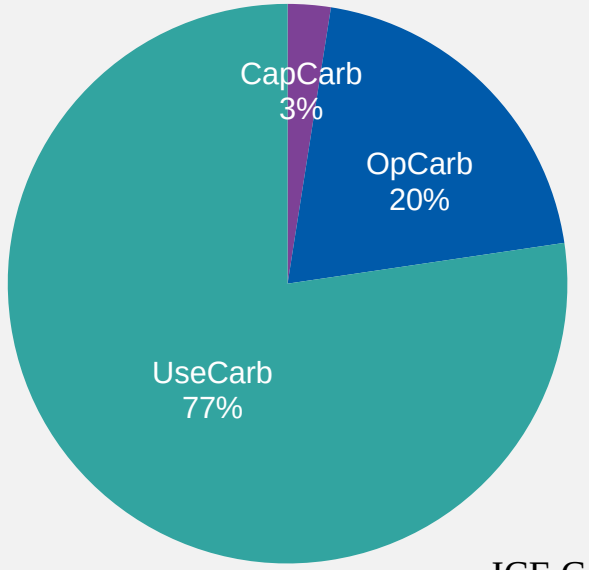
Whole Life Carbon



Breakdown of capital, operational and user carbon for the UK Infrastructure sector in 2018



ICE Carbon Project, 2020

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A1-A3

	CLIC 5.6m dia.	CLIC 10m dia.	ILC 9.5m span
Location	Geneva	Geneva	Japan
Materials	CEM1 Steel fibre Steel reinforcement B500B Rock bolts	CEM1 Steel fibre Steel reinforcement B500B Rock bolts	CEM1 Steel fibre Steel reinforcement B500B Rock bolts
Assets	Precast segments for tunnel lining, caverns, access shafts	Precast segments for tunnel lining, caverns, access shafts	TBC
Database	TBC	TBC	TBC
Key assumptions	As per query log - CLOSED	As per query log - CLOSED	As per query log - OPEN
Exclusions	Temporary buildings, water consumption, production of construction machine, operational period		

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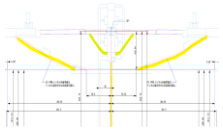
ILC Query Log

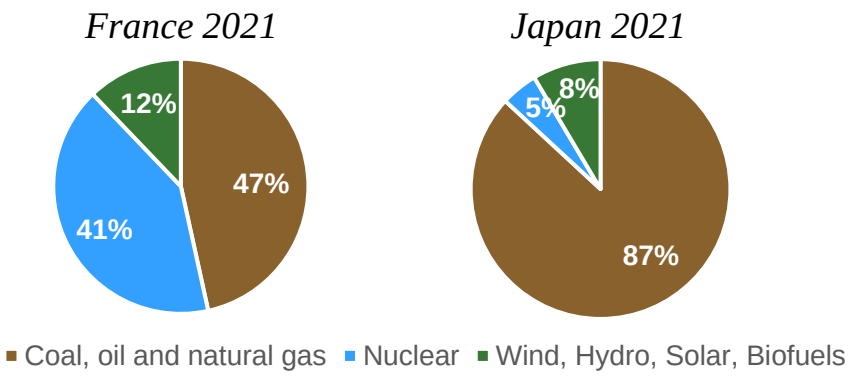
	Arup Comment			CERN Comment	Agreement
	DOCUMENT REFERENCE	COMMENT	COMMENT CODE	RESPONSE	Status
1	General	Can IFC/CAD/Rhino files be provided (shown as isometric views in presentations)	A	Contact with KEK in progress to provide.	Open
2	General	Please provide an ILC assumptions list similar to that provided for CLIC, if possible. (Lining thicknesses, steel quantity, construction method etc.)	A	Contact with KEK in progress to provide.	Open
3	General	Please provide a long section of the ILC tunnel, detailing construction method, advance rate and RMR for the different assets (tunnels, shafts, caverns)	A	Contact with KEK in progress to provide.	Open
4	Slide 16, ILC Overall Tunnel Design Hayano 03172021.pdf	Please provide an end to end schematic layout of the ILC with the 3 tunnel cross sections (A-A, B-B, C-C) as detailed in slide 16 of ILC Overall Tunnel Design Hayano 03172021.pdf	A	Contact with KEK in progress to provide.	Open
5	Slide 22, ILC Overall Tunnel Design Hayano 03172021.pdf	Please provide cross sections of tunnels highlighted. 	A	Contact with KEK in progress to provide.	Open
6	Slide 12 and 13, ILC Civil Engineering Overview.pdf	Utility hall dimensions have not been provided, however 38,500m3 volume has - please clarify if this is correct assumption.	B	Contact with KEK in progress to provide.	Open
7	Slide 6, ILC Civil Engineering Overview.pdf	Please provide cross section of access tunnels and slope of tunnel. Length of access tunnels has been provided.	B	Contact with KEK in progress to provide.	Open

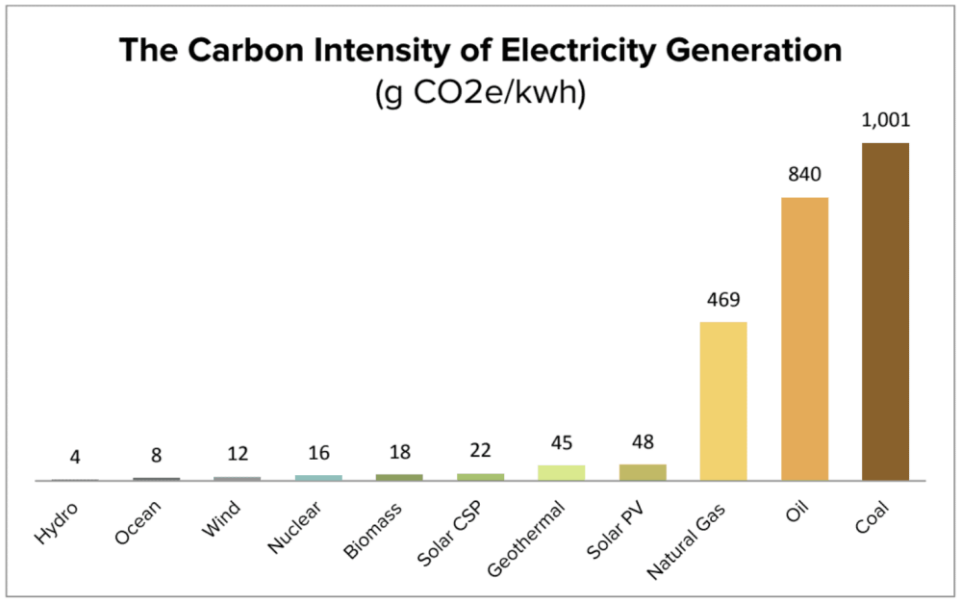
A4-A5

	CLIC 5.6m dia.	CLIC 10m dia.	ILC 9.5m span
Excavation method	TBM and mechanised SCL, advance rate 16-20m per day	TBM and mechanised SCL, advance rate of 12-16m per day	D&B and mechanised SCL
Fuel type	Electricity from grid, diesel generators	Electricity from grid, diesel generators	Electricity from grid, diesel generators
Energy data	TBC	TBC	TBC
Transport (site to disposal site)	Mode: Road Distance: 20km	Mode: Road Distance: 20km	Mode: TBC Distance: TBC
Transport (manufacturers to site)	Mode: Road Distance: 30km	Mode: Road Distance: 30km	Mode: TBC Distance: TBC
Key assumptions	Other tunnels, caverns and alcoves will be mined excavations (road header/rock breaker) Advance rate of mined construction to be 300 m3 per day for caverns or 10 m per day for mined tunnels	Other tunnels, caverns and alcoves will be mined excavations (road header/rock breaker) Advance rate of mined construction to be 300 m3 per day for caverns or 10 m per day for mined tunnels	Hard rock within unknown ground characteristics
Exclusions	Temporary structures (launch portals receiving shafts, TBM launch cradles), operational period		

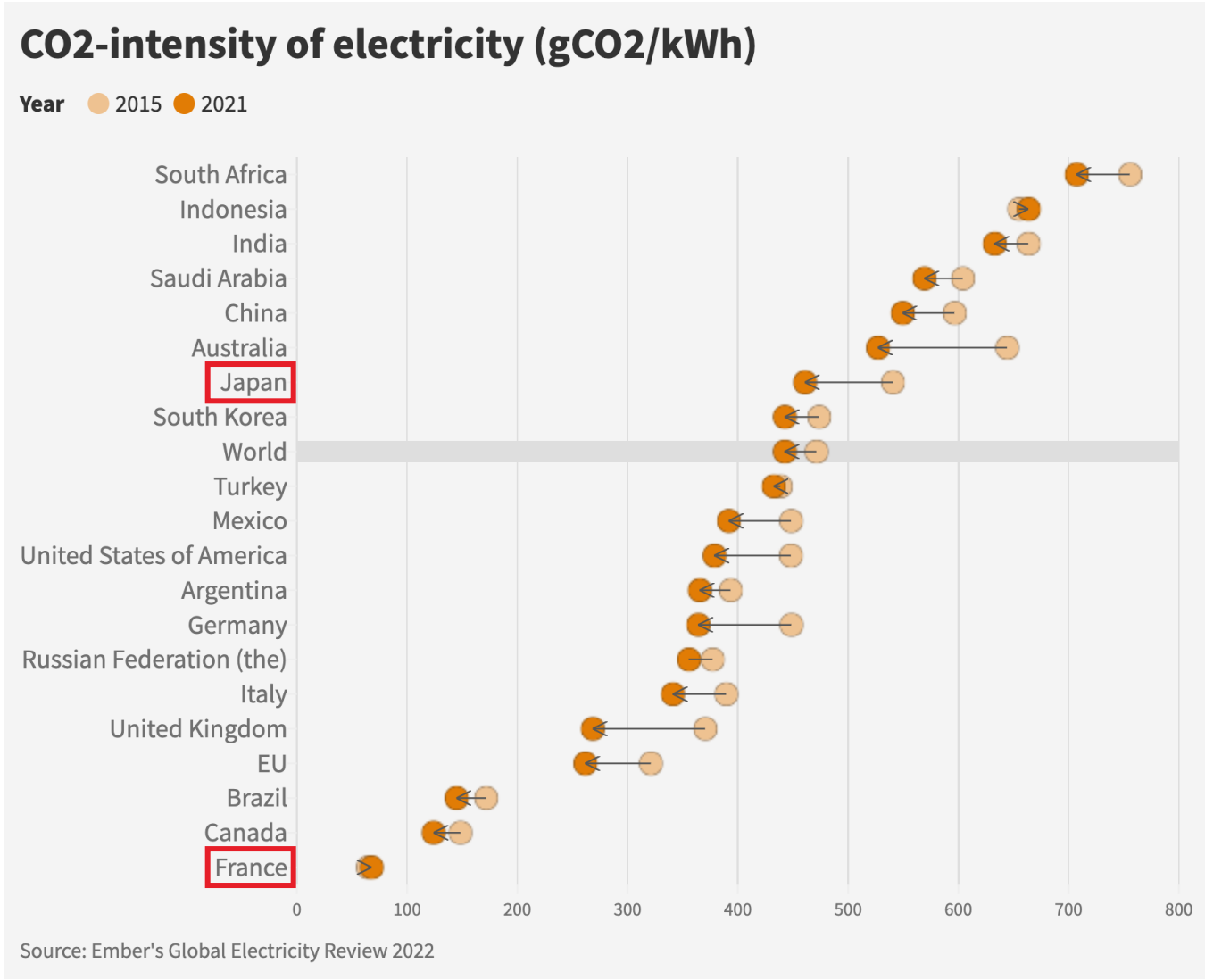
Carbon Intensity of Electricity

Total energy supply by source (IEA 2023)





Source: Adapted from IPCC special Report on Renewable Energy Sources and Climate Change Mitigation.



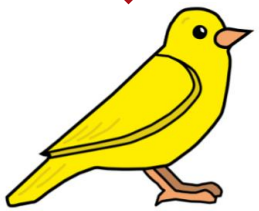
Tools Workflow

A1-A5 Inputs
(Geometry, materials, transport and construction activities data)

LCA tool evaluating chosen environmental impact categories

One Click LCA

A1-A5 Outputs
Evaluates chosen environmental impact categories



Canary
Carbon calculator for Grasshopper

Arup tool.
Parameterised model evaluating A1-A5 carbon impacts

Optioneering

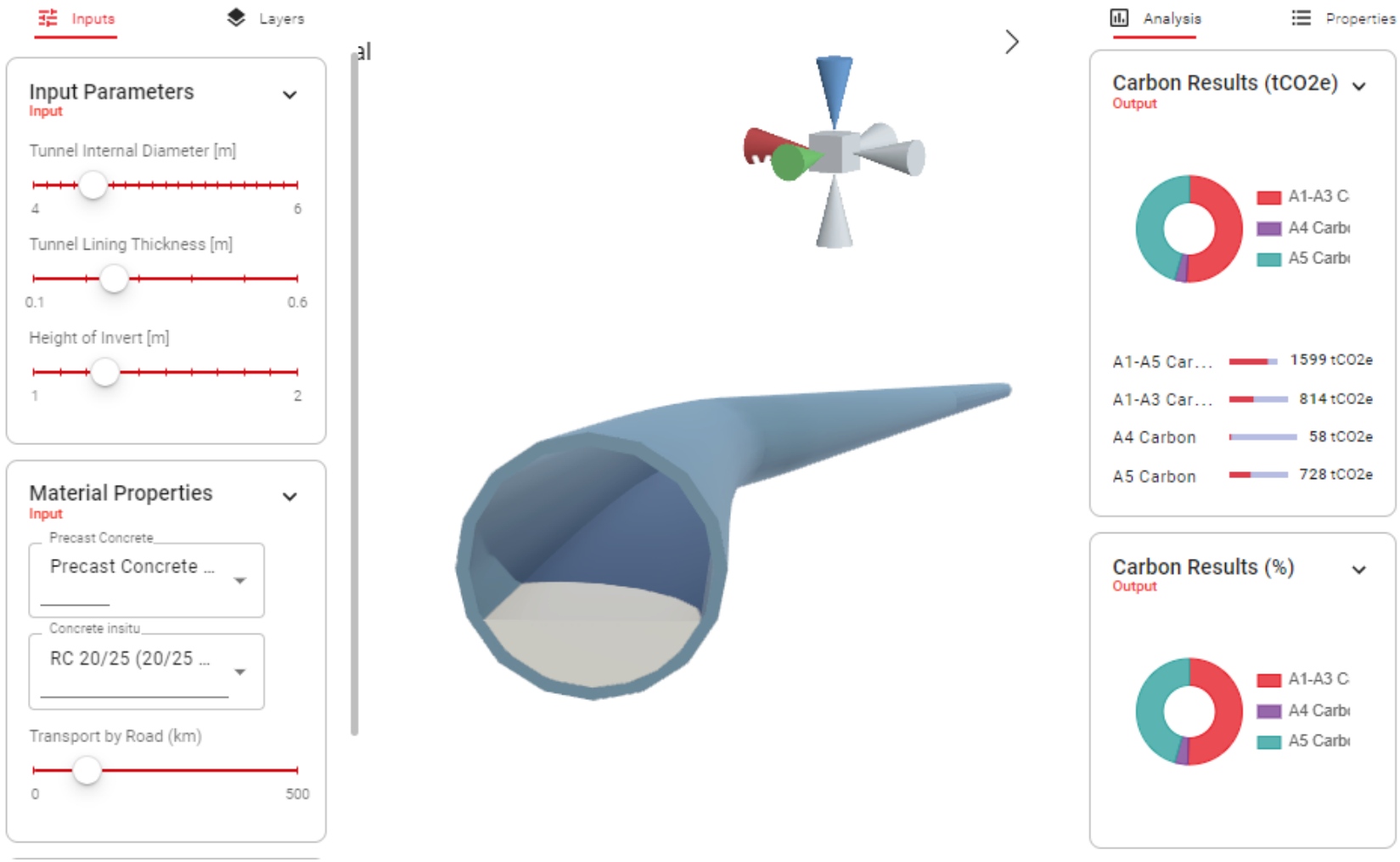
Arup Inform

Quickly compare and explore numerous design solutions to make informed decisions.

Visualisation of model allowing real time parameter changes and corresponding carbon impacts

A1-A5 Outputs
Evaluates CO2 emissions only

inForm Example



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Next Steps

Key activities

Phase 1 (- Feb)

- Stage 1: Finalise desk study outcomes and design intent clarifications
- Stage 2A: A1-A3 assessment: Confirm factors and approach, digital model integration, parametric modelling

Phase 2 (Feb - May)

- Stage 2B: A4-A5 assessment

Phase 1 & 2 (Feb – Apr)

- Stage 3: Future considerations research

Next Steps

Future considerations research

1. **Trends in materials:** CEM I, mix design, grouting, reinforcement alternatives etc
2. **Future carbon pricing mechanisms:** Internal carbon pricing, ETS, carbon tax etc
3. **CERN/KEK net zero targets:** Tohoku CO2 neutrality 2050. CERN targets? Paris agreement alignments

Tunnel specific energy and carbon factors: Databases - suppliers, contractors, past projects, ITA

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