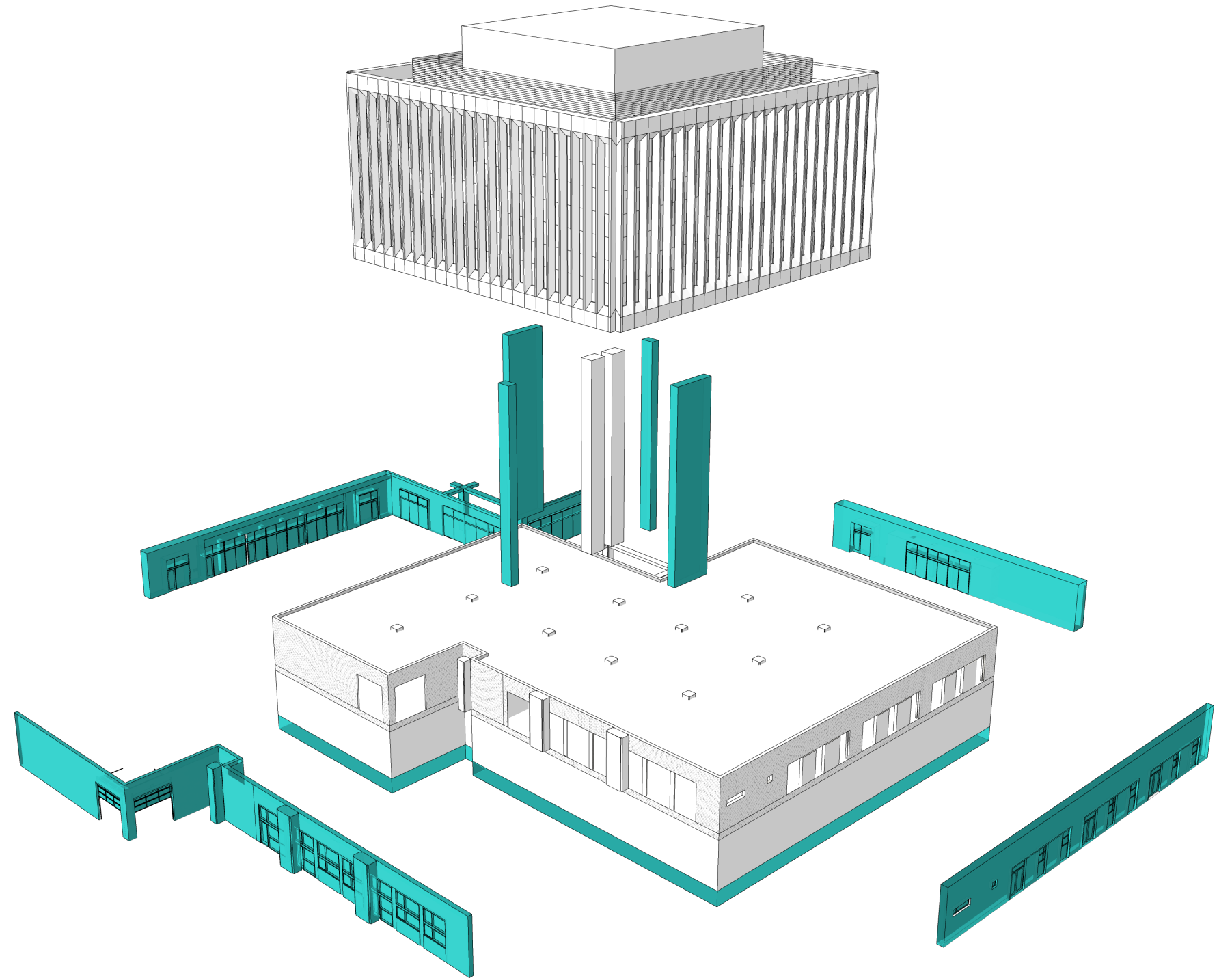


Exploded diagram

This diagram was created for the Santa Ana Arts Collective Embodied Carbon Analysis, highlighting The SAAC EC and Waste Story.

For this assignment, I was provided a complex SketchUp model of a developed complex and was asked to highlight a given building within the space. I removed the complexities surrounding the building, and created the exploded diagram, detaching sections and adding structural pieces, along with exploding the walls from the existing building.

Programs: SketchUp



Roadmap

The sustainable concrete roadmap summary was prepared by Arup as part of its mandate to review McGill University's existing concrete design standard to incorporate sustainability initiatives.

Programs: InDesign, Illustrator

Sustainable concrete roadmap summary

This sustainable concrete roadmap summary was prepared by Arup as part of its mandate to review McGill University's existing concrete design standard to incorporate sustainability initiatives.

14 April 2022

Carbon impacts of concrete

Strategies to reduce embodied carbon in concrete

1 | Design

2 | Material specification

3 | Setting limits

4 | Procurement

1 Design

- Reuse and renovate existing structures as much as possible
- Adopt appropriate design loads
- Adopt efficient slab systems
- Optimized and appropriate design
- Specify concrete strength to avoid over specification
- Specify appropriate type of concrete (cast-in-place, precast, prestressed) for right construction context
- Relax the age at which the target design strength is achieved

2 Material specification

Standardized initiatives	Portland cement	Aggregates	Supplementary cementitious materials	Reinforcement
	Portland limestone cement	<ul style="list-style-type: none"> - High-strength aggregates - Well graded aggregates - Avoid lightweight aggregates - Recycled aggregates - Secondary aggregates 	<ul style="list-style-type: none"> - Ground granulated blast furnace slag - Fly ash - Silica fume - Ground glass pozzolans - Natural pozzolans - Calcinated natural pozzolans 	Higher-grade steel reinforcement
Low carbon proprietary technologies	<ul style="list-style-type: none"> - CarbonCure - CarbiCrete - Synergis Ciment Quebec - Solida 	Carbon negative aggregates	Carbon upcycling	

261 kgCO₂e/m³
Total embodied carbon excluding reinforcement

Mix proportions and carbon footprint of a typical Portland cement concrete

	Portland Cement ^A	Water ^A	Coarse Aggregate ^C	Fine Aggregate ^C	Supplementary Cementitious Materials ^D
GWP Factor ^E (kgCO ₂ e/ton)	940.50 ^F	0.06	4.82	4.82	184.60
Mix proportions ^G	251.00	156.00	782.00	1046.00	84.00
Embodied carbon (kgCO ₂ e/m ³)	236.00	0.01	4.00	5.00	16.00
% Volume of concrete	11	7	34	45	4
% Embodied carbon of concrete	91	0	1	2	6

3 Setting limits

Setting cement and embodied carbon limits against industry averages

Figure 2 Embodied Carbon Limits
Figure 2 above presents the embodied carbon limits provided under EPD10902 for Portland Limestone Cement (GLC) with varying type and level of cement replacement and the industry average benchmark. For comparison limits set out by the Metric County guidelines are also presented. The proposed limits for McGill University are based on higher levels of cement replacement. Due to limitations of Arup's scope, these limits have not been tested within the local market during the preparation of this note.

4 Procurement

- **Local availability and responsible sourcing:** Not all supplementary cementitious materials and low carbon technologies are readily available in all regions in a continuous form of supply. Locally sourced materials can have a lower carbon footprint when transportation is accounted for.
- **Standards, specifications and regulations:** Specified measures should meet local standards, as well as client specifications and regulations. This applies more to proprietary technologies.
- **Appropriate applications:** As mentioned previously, solutions should be implemented for the right applications.
- **Available information:** It is key to obtain as much information as possible. Testing may be required.
- **Previous experience:** Any past projects can help to determine if the application of the technology is right for the project. Any past experience from the stakeholders can also influence whether the solution can be used or not.
- **Identification of applicable structural and durability-related properties needed for design:** It is also key to identify these properties to ensure that the product meets the requirements, even if additional tests may be required.
- **Favour local supply for sustainable procurement.**
- **Availability of products will also vary in time.**

Disclaimer:
Not all solutions presented within this paper are appropriate for every project, and it is important for design teams to undertake a final assessment for each project. The data are non-exhaustive examples of concrete strategies, many more exist. A more in-depth review by an engineer and material expert in the field, as well as collaboration with project stakeholders shall take place.

Concrete mix embodied carbon case studies

Figure 1 Embodied carbon of concrete mixtures

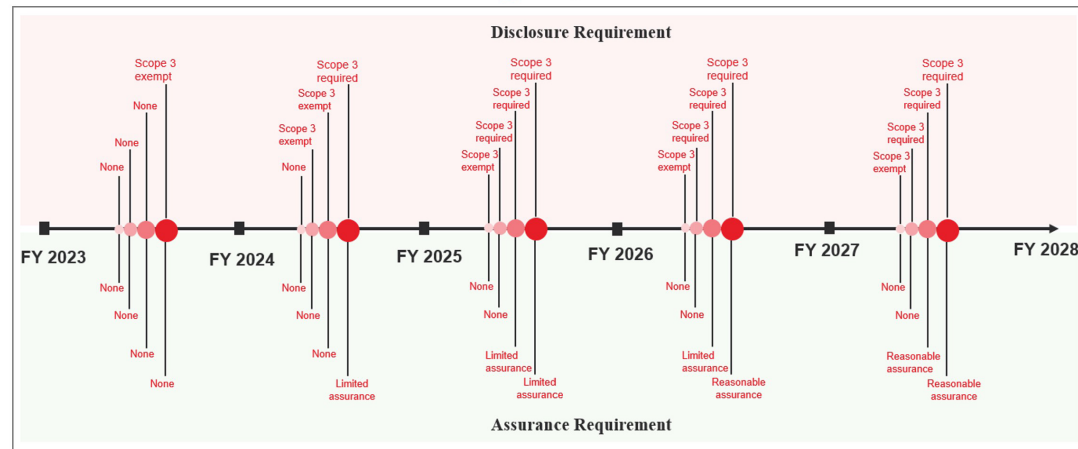
Notes:
1. The first pie chart represents a standardized concrete mixture. It is CRMA mix#11, 30 MPa with 20% slag and Portland cement (GLC). It contains no steel reinforcement.
2. The second pie chart represents a reinforced concrete mixture, CRMA mix#11, 30 MPa with 20% slag and GLC cement. It contains 400 MPa steel reinforcement.
3. The third pie chart represents a lower carbon reinforced concrete mixture, CRMA mix#15, 30 MPa with 35% slag and GLC cement. It contains 400 MPa steel reinforcement.
4. The fourth pie chart represents a lower carbon reinforced concrete mixture, CRMA mix#16, 30 MPa with 35% slag and Portland limestone cement (GLC). It contains 400 MPa steel reinforcement.
5. The fifth pie chart represents a lower carbon reinforced concrete mixture, CRMA mix#16, 30 MPa with 35% slag and GLC cement. It contains 500 MPa steel reinforcement. Assumed recycled content of 500MPa is similar to 400MPa grade.
6. The design for pie charts 2, 3, 4 and 5 is for a 230 mm thick suspended slab.
7. The figure first shows the significant impact of carbon on the embodied carbon of a reinforced concrete slab. The impact increases from 260 kgCO₂e/m³ to 383 kgCO₂e/m³. However, by introducing a higher slag percentage to replace cement, the embodied carbon decreases to 277 kgCO₂e/m³ and by switching to GLC cement, it decreases to 234 kgCO₂e/m³. Finally, by selecting higher strength steel, the embodied carbon is further reduced to 401 kgCO₂e/m³ for a 21% reduction from mix 2. This is achieved through a standardized approach.
8. The lower carbon reinforced concrete mixes (3, 4, 5) do not represent an aggressive low carbon concrete mix. The mixes were selected for their data availability and transparency from Concrete Canada. All mixes are from a Cradle-to-Cradle Life Cycle Assessment of Ready-Mix Concrete Manufactured by CRMA Members, Adhara Sustainable Materials Institute. The GWP values for each constituent are from Table 1.

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Timeline

The timeline highlights the phased approaches to disclosure and financial assurance requirements. This graphic was part of the SEC proposal document, outlining the new ruling for financial disclosure.

Programs: InDesign, Illustrator



Original provided graphic

Assurance and time horizon SEC ruling

Phased approaches to disclosure and financial assurance requirements

Registrants or public equity entities

- None accelerated filer: < \$75m revenue; emerging growth
- Small reporting companies: < \$100m revenue
- Accelerated filer: > \$250m < \$700m revenue
- Large accelerated filer: > \$700m revenue

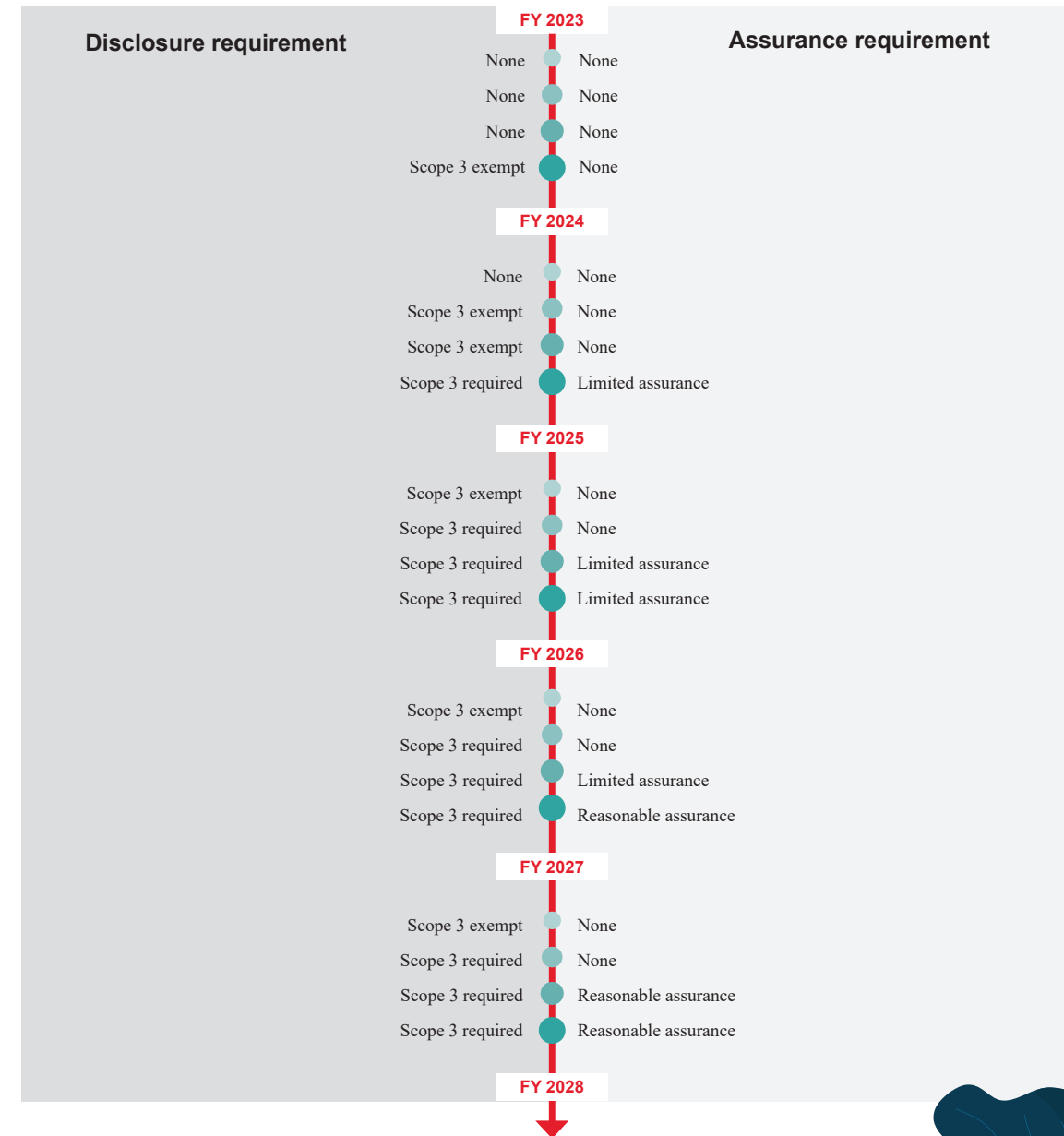


Figure 6

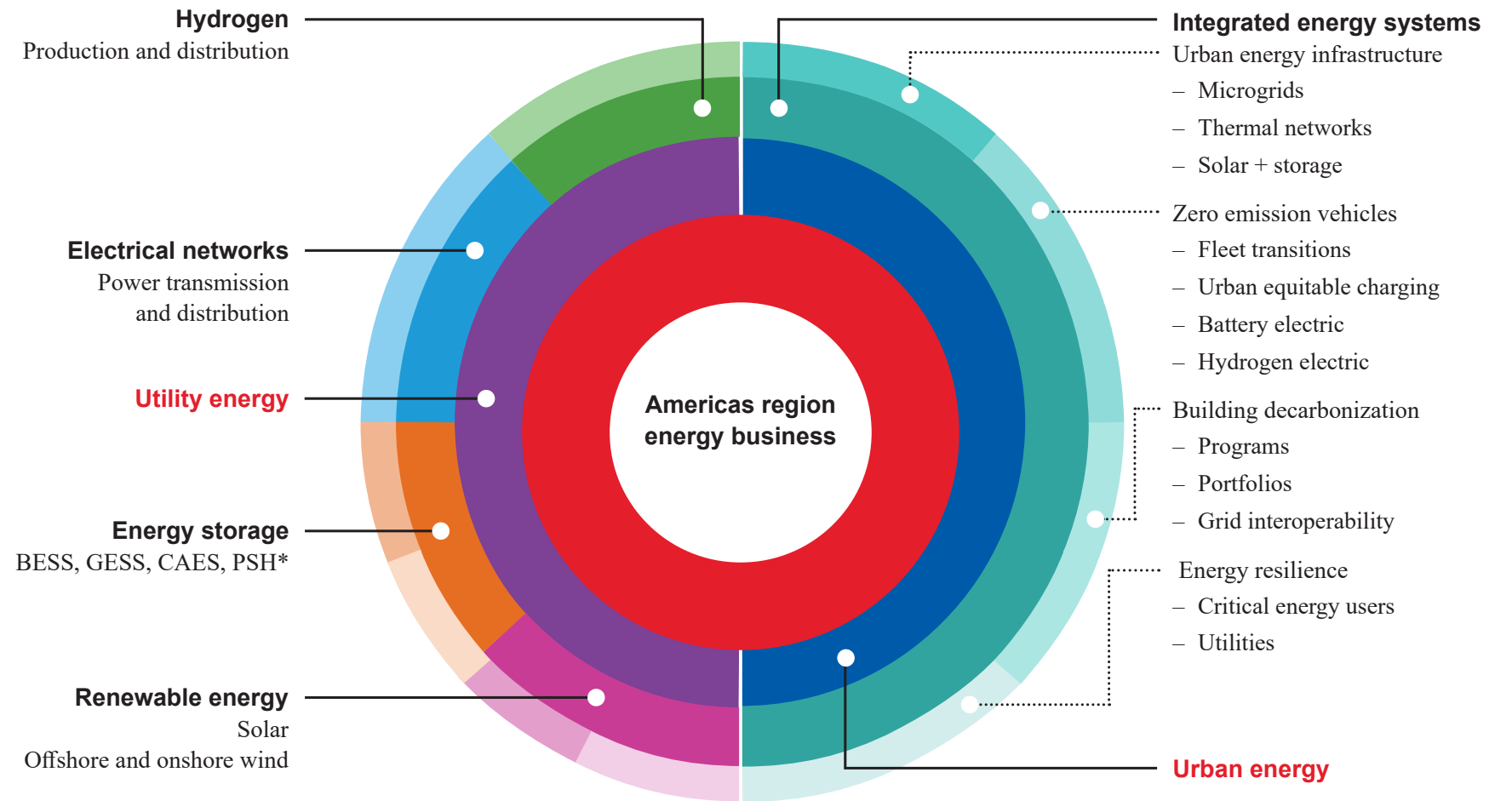
The U.S. SEC proposed rule adopts a phased approach for disclosure and financial assurance requirements.



Concentric graphic

This graphic was part of the Renewable Energy Systems qualifications document and details the various services centred around Arup's Americas region energy business.

Programs: InDesign, Illustrator



*Energy storage acronyms

BESS — Battery energy storage system
GESS — Gravity energy storage system
CAES — Compressed air energy storage
PSH — Pumped storage hydropower