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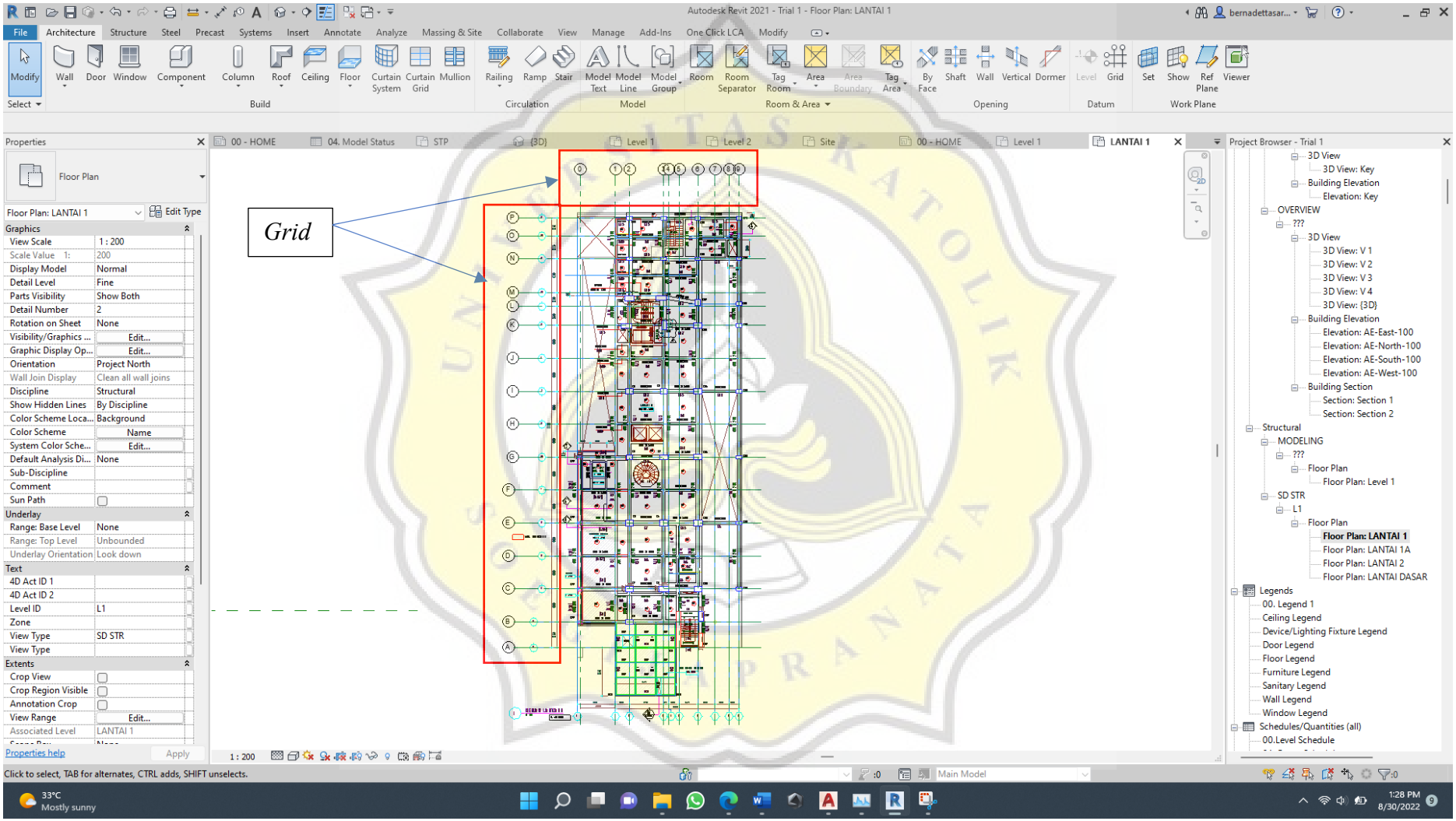
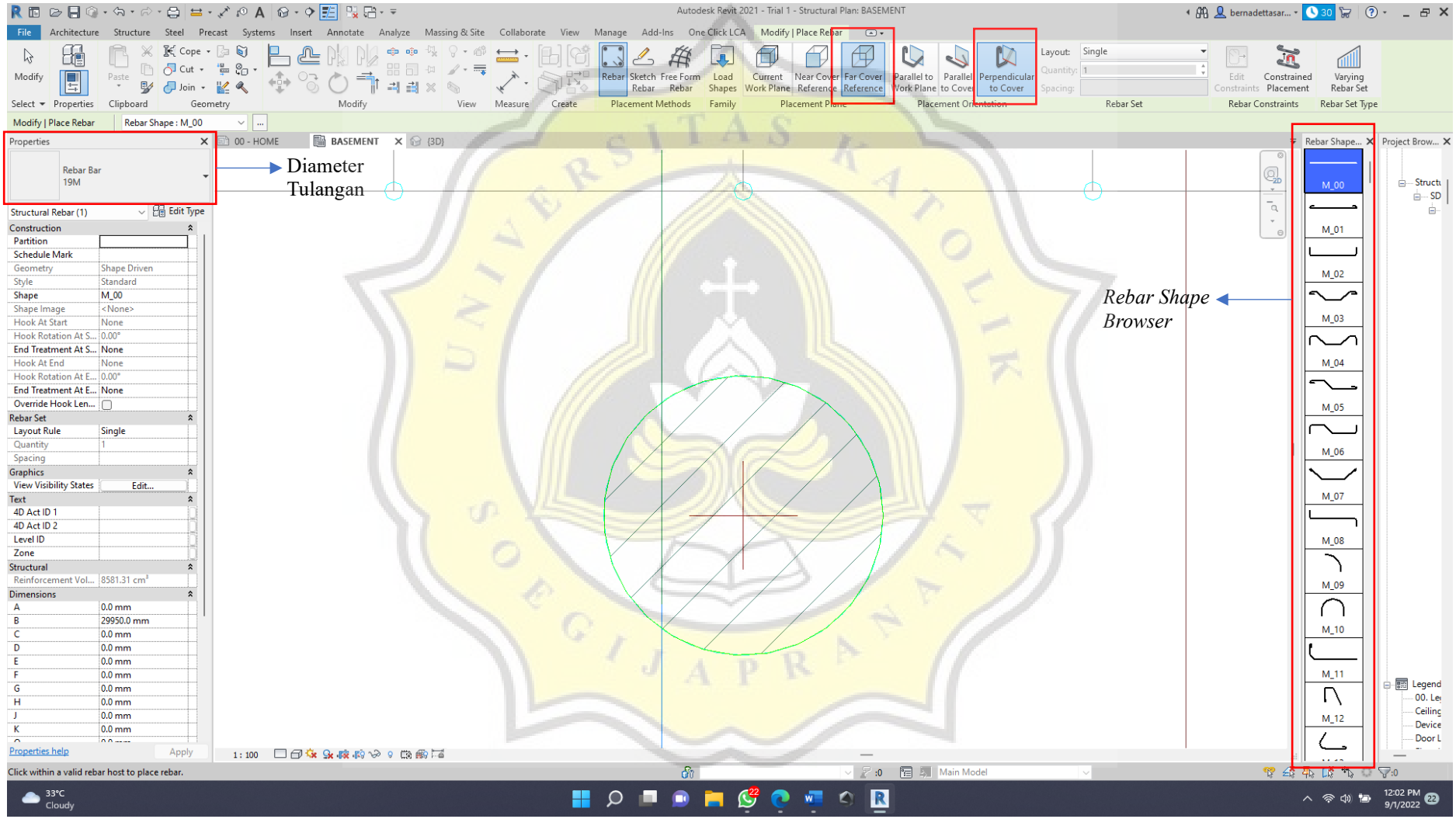
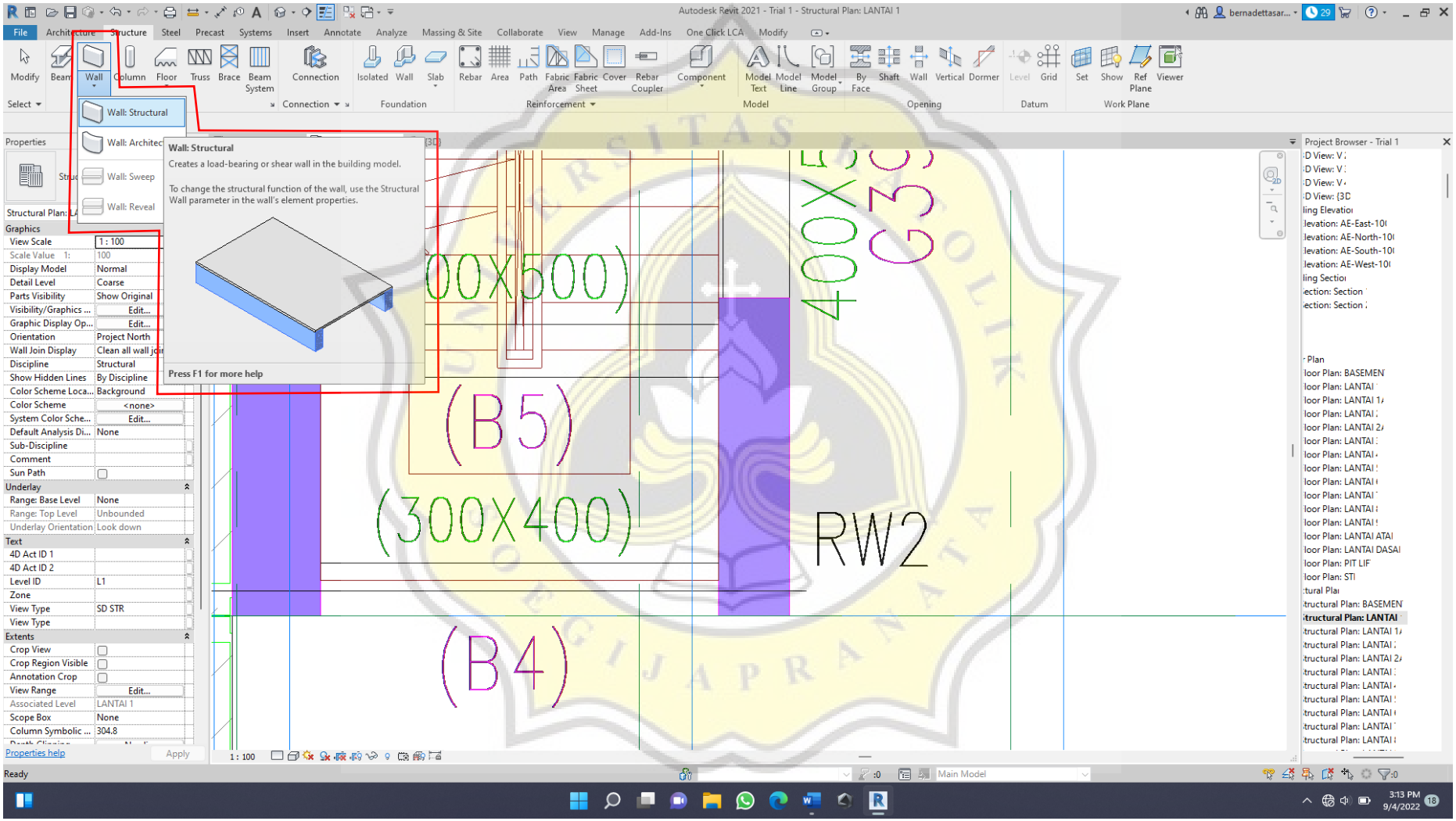
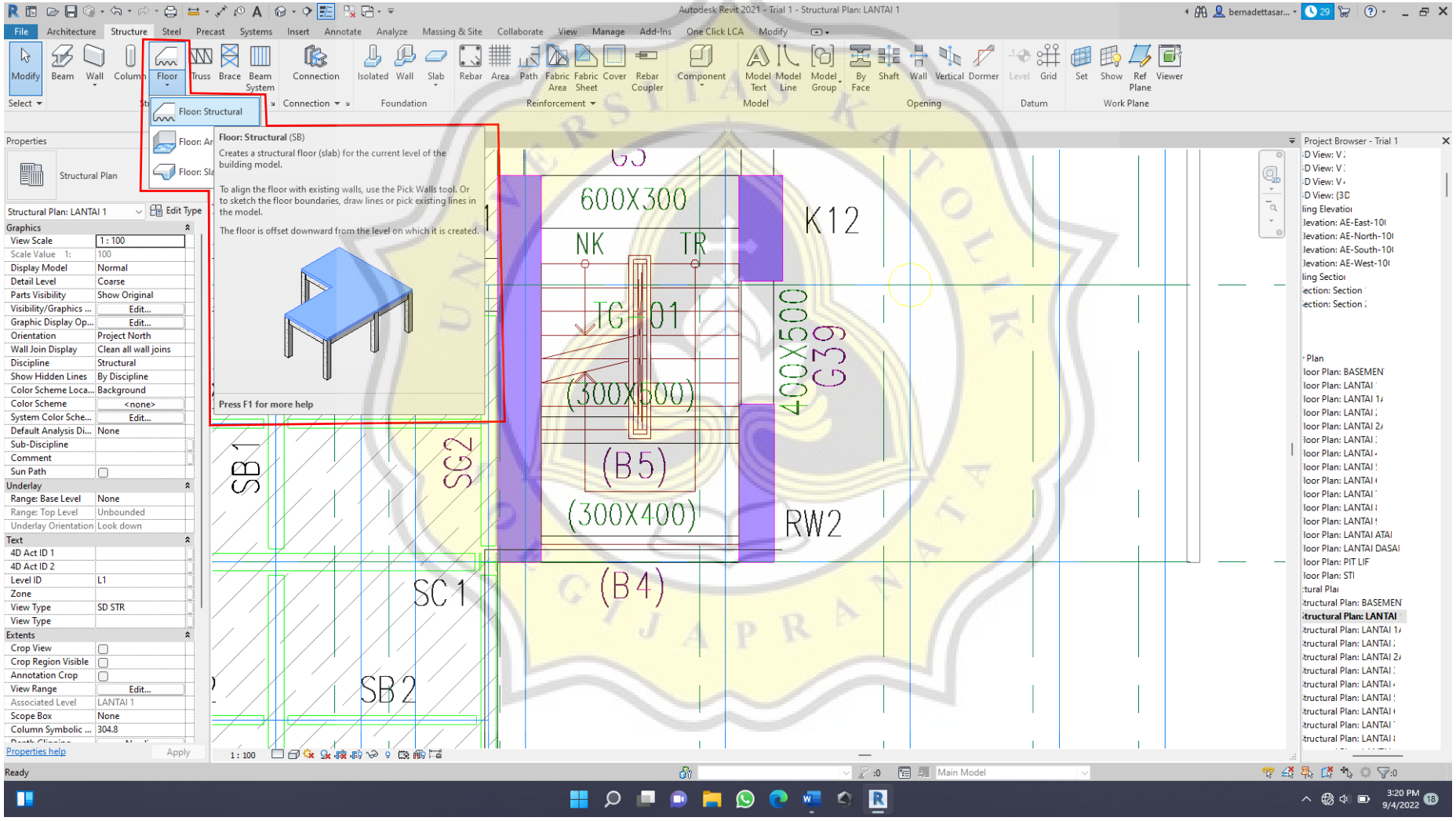
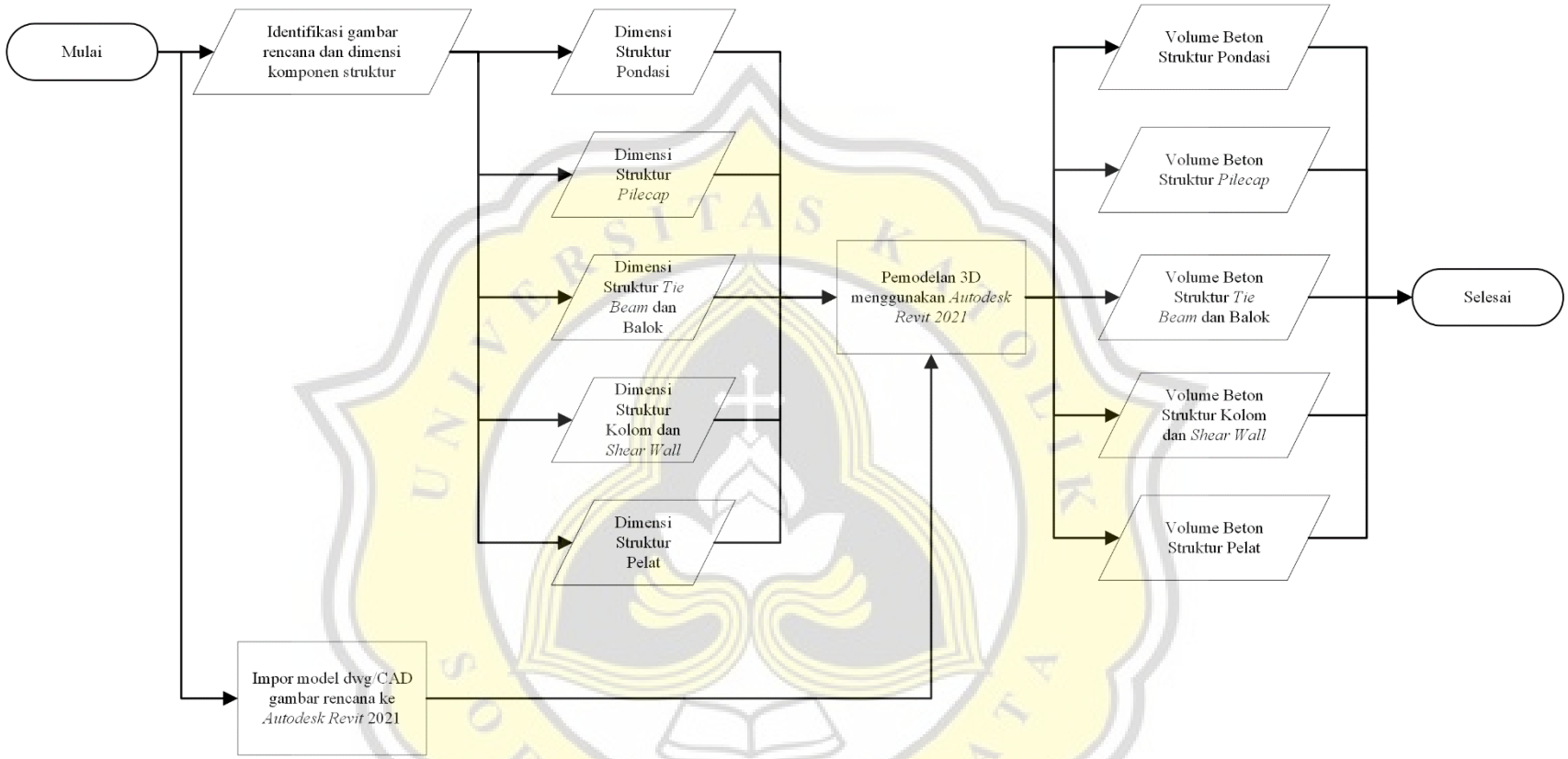

Grid


Diameter Tulangan
Rebar Shape Browser

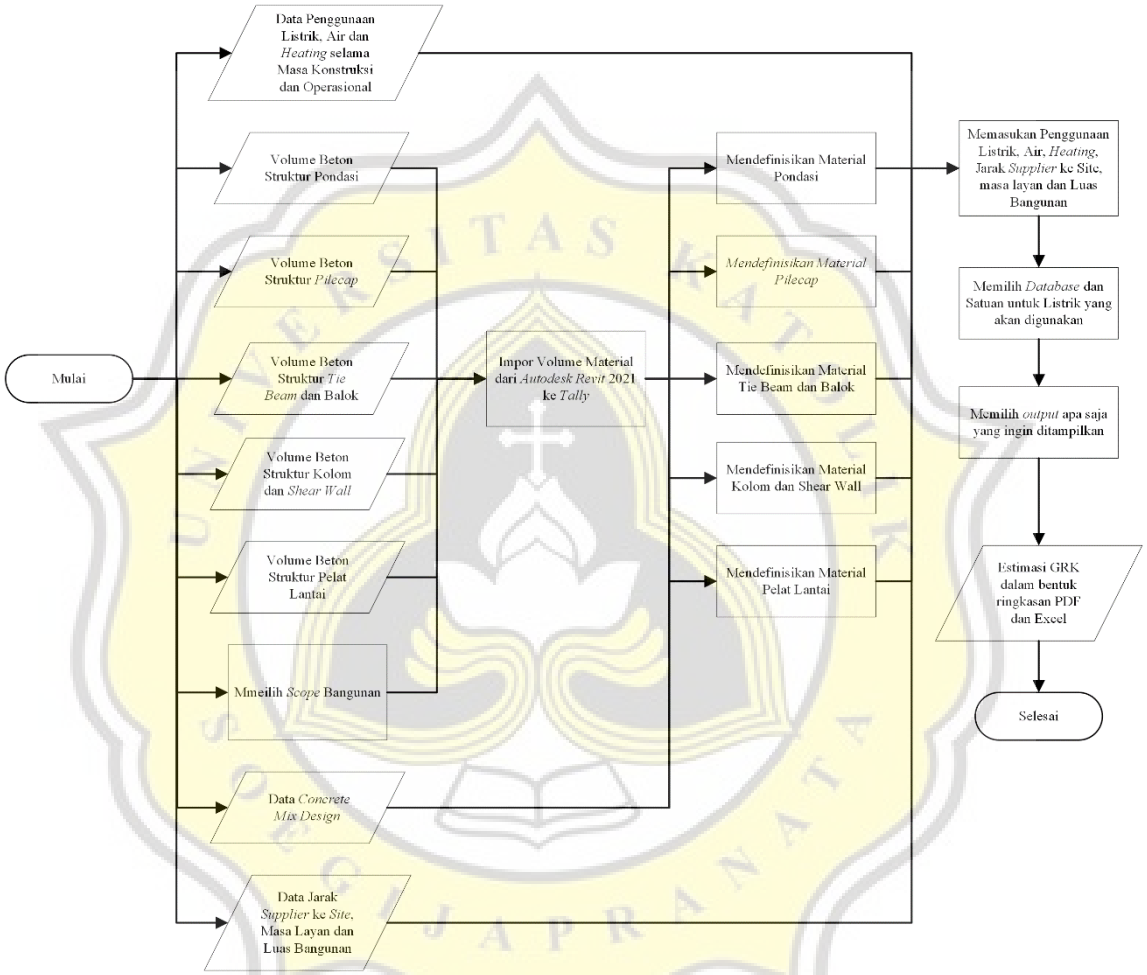

Autodesk Revit 2021 - Trial 1 - Structural Plan: LANTAI 1
Wall: Structural
Creates a load-bearing or shear wall in the building model.
To change the structural function of the wall, use the Structural Wall parameter in the wall's element properties.
Press F1 for more help
(B5)
(300X400)
(B4)
RW2
400X3
00X500)


Autodesk Revit 2021 - Trial 1 - Structural Plan: LANTAI 1
Floor: Structural
Floor: Structural (SB)
Creates a structural floor (slab) for the current level of the building model.
To align the floor with existing walls, use the Pick Walls tool. Or to sketch the floor boundaries, draw lines or pick existing lines in the model.
The floor is offset downward from the level on which it is created.
Press F1 for more help
600X300
K12
NK
TR
TG 01
(300X500)
400X500
G39
(B5)
(300X400)
RW2
(B4)
SB1
SG2
SC1
SB2
Properties
Structural Plan: LANTAI 1
Project Browser - Trial 1
Ready

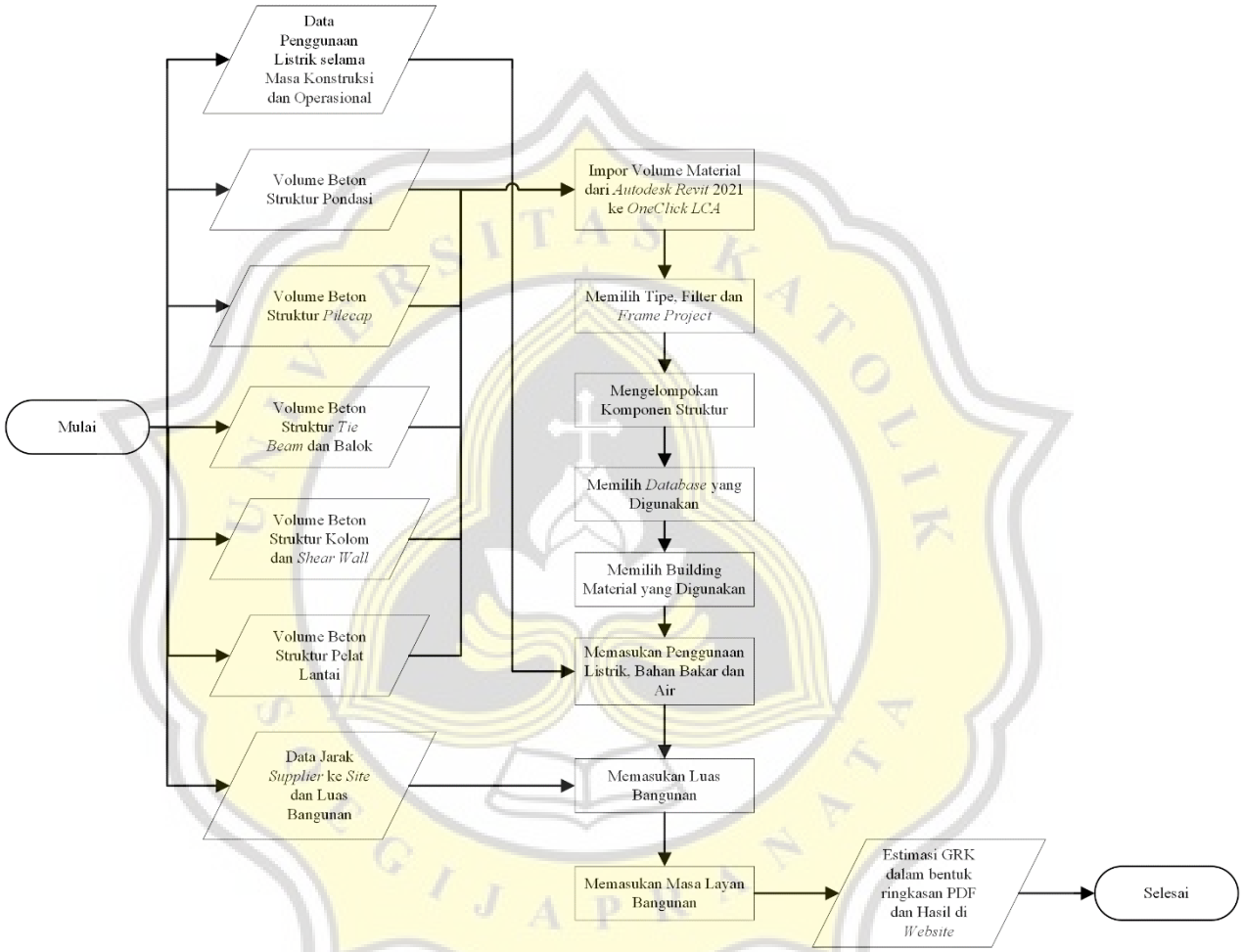
LAMPIRAN B



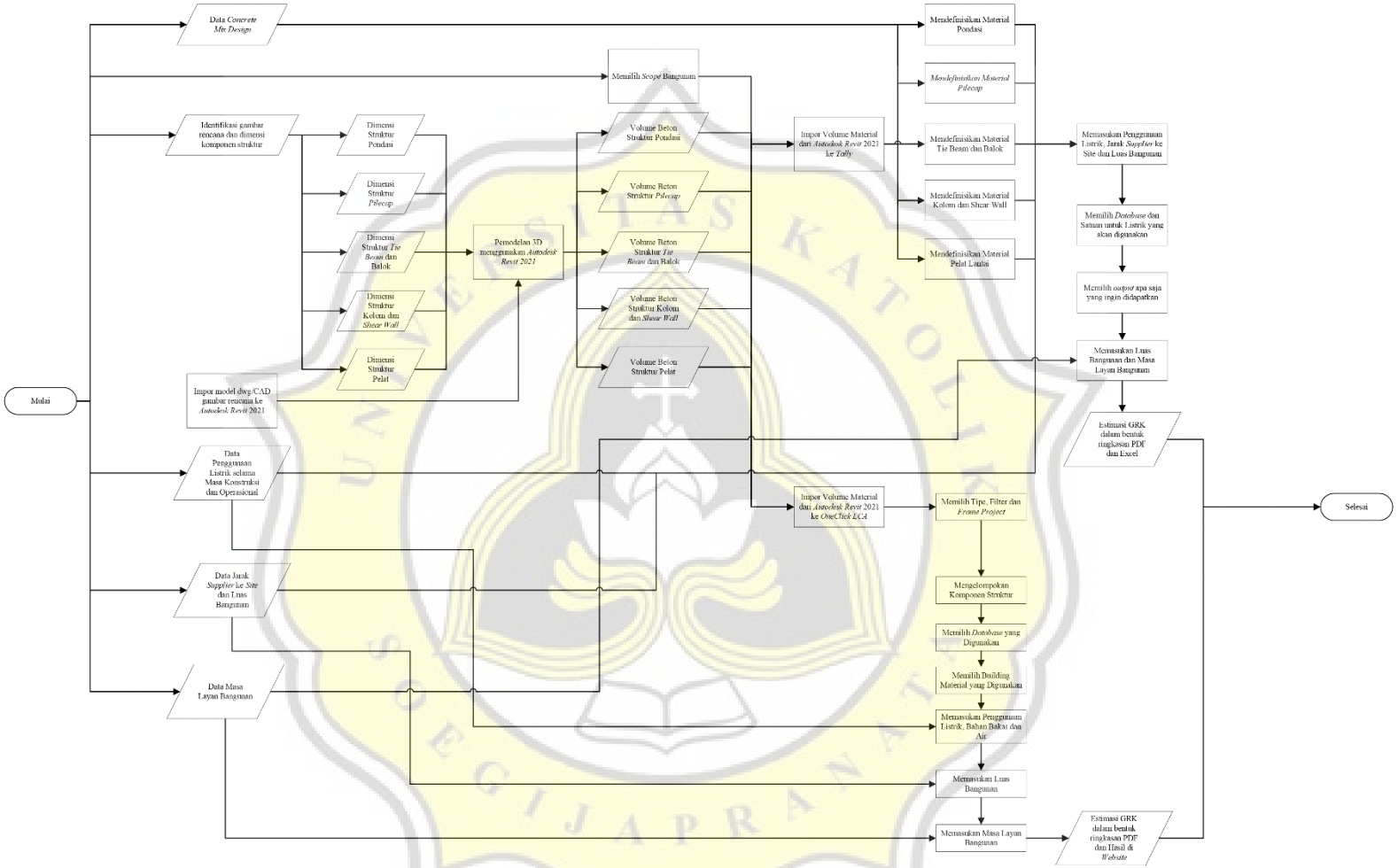
Gambar 1. Bagan Alur Pemodelan 3D menggunakan *Autodesk Revit 2021*



Gambar 2. Bagan Alur Pengaplikasian *Tally*



Gambar 3. Bagan Alur Pengaplikasian *OneClick LCA*



Gambar 2. Bagan Alur Seluruh Tahapan BIM *Based*-LCA oleh *Tally* dan *OneClick LCA*

No.	Uraian	*OneClick LCA*	*Tally*
1.	Data yang input	a. Volume beton bangunan b. Data penggunaan listrik selama masa konstruksi dan operasional c. Data jarak supplier menuju lokasi proyek d. Data luas bangunan	a. Volume beton bangunan b. Data penggunaan listrik selama masa konstruksi dan operasional c. Data jarak *supplier* menuju lokasi proyek d. Data luas bangunan e. Data *concrete mix design*
2.	Melakukan *import data*	Terdapat 7 langkah dalam mengimpor data pada OneClick LCA a. Data Data otomatis terhubung dari Revit, tidak dapat diubah b. Settings Memilih nama proyek, desain baru, dan alat kalkulasi yang akan digunakan untuk proses impor data. Memilih juga tahapan proses kontruksi yang akan dianalisis, jenis proyek (konstruksi baru, renovasi dan atau pengembangan bangunan yang sudah ada, dll), memilih frame type (concrete, steel, timber frame, dll) c. Classify Mengelompokan komponen struktur menjadi beberapa klasifikasi baru.	Langkah mengimpor data pada *Tally* : 1. Memilih *scope* bangunan kemudian pilih *apply* 2. Memilih komponen apa saja yang hendak dihitung 3. Memilih fase apa saja yang hendak dihitung kemudian klik *apply*

No.	Uraian	*OneClick LCA*	*Tally*
		d. Filter Melakukan penyaringan yang didasarkan dari tahap Clasiffy. Pengelompokan dilakukan berdasarkan klasifikasi dalam impor pemodelan. Apabila ada data yang tidak diperlukan, dapat dihapus centangnya sehingga komponen tersebut tidak akan diproses. e. Combine Jika data pada semua kolom dalam suatu kriteria pengelompokan sama, maka data tersebut akan digabungkan menjadi satu baris. Kriteria pengelompokan dapat disesuaikan kebutuhan, dengan menghapus atau menambahkan centang pada kotak. f. Review Melakukan pengecekan ulang dari kriteria pengelompokan. g. Mapping Software akan secara otomatis mengidentifikasi kumpulan data yang mirip dengan yang telah dipetakan sebelumnya. Peta kumpulan data ini akan digunakan dalam urutan prioritas: pemetaan sendiri, pemetaan organisasi, pemetaan negara yang sama, dan semua	

No.	Uraian	*OneClick LCA*	*Tally*
		pemetaan (termasuk pemetaan sistem, nama lengkap, dan kumpulan aturan pengenalan default). Pemetaan juga mempertimbangkan properti lain dari kumpulan data yang diimpor, seperti klasifikasinya. Selain itu dapat mengubah pemetaan apa pun yang diinginkan, dan perubahan akan diingat secara otomatis. Jika tidak dapat mengidentifikasi materi, atau tidak dapat mengukurnya, materi mungkin tidak akan diimpor. Namun jika dapat memetakannya ke salah satu sumber daya, akan dapat diimpor secara otomatis.	
3.	Proses	a. Memasukkan data jumlah konsumsi energi berupa konsumsi listrik dan konsumsi bahan bakar b. Memasukkan luas bangunan. Angka yang diinput tidak termasuk tempat parkir dan sirkulasi kendaraan bermotor, tetapi sudah termasuk ruang bawah tanah. c. Memasukkan masa layan bangunan	a. Mendefinisikan material yang digunakan pada setiap komponen struktur. b. Memasukan penggunaan listrik, air dan *heating* baik pada saat masa konstruksi maupun operasional, jarak *supplier* ke site dan luas bangunan. c. Memilih *database* dan satuan untuk Listrik, *Heating* dan Air yang digunakan. d. Memilih *output* apa saja yang hendak ditampilkan
4.	*Output*	a. Terdiri dari file dengan format PDF.	a. Terdiri dalam file dengan format PDF dan excel (.xls)

No.	Uraian	*OneClick LCA*	*Tally*
		b. File PDF berisikan identitas proyek, hasil estimasi LCA dari masing-masing tahapan daur hidup, material yang paling berpengaruh bagi pemanasan global, serta visualilasi hasil estimasinya berupa bagan. c. Indikator GRK dibagi menjadi 6 kategori yaitu *Global Warming* (Co_2e), *Acidification* (SO_2e), *Eutrophication* (PO_4e), *Ozone Depletion* ($CFC_{11}e$), *Formation of Ozone of Lower Atmosphere* (*Ethenee*), dan *Total Use of Primary Energy ex. Raw Materials*. d. Tahapan daur hidup bangunan dikelompokan berdasarkan EN 15978. e. Hasil LCA dikelompokan menjadi 4 kelompok, yaitu berdasarkan daur hidup bangunan (*life cycle stage*), klasifikasi tiap komponen, sumber bahan baku (*resource types*), dan berdasarkan massa per komponen.	b. File PDF berisi rangkuman dari hasil estimasi LCA bangunan, sedangkan file excel berisi detail estimasi dan keterangan yang didapatkan dari setiap komponen c. Pada file PDF, hasil LCA dikelompokan menjadi 9 kelompok yaitu berdasarkan *environtmental impact totals*, *environtmental impacts/area*, *results per life cycle stage*, *results per life cycle stage berdasarkan division*, *results per division*, *results per division itemized by tally entry*, *results per division itemized by material*, *results per revit category*, *results per revit category itemized by family*, *results per building element*. d. Tahapan daur hidup bangunan dibagi berdasarkan EN 15978 e. Terdapat 5 indikator GRK yang kategori dan faktornya dibuat berdasarkan Traci 2.1 yang dibuat oleh *United States Environtmental Protective Agent.*

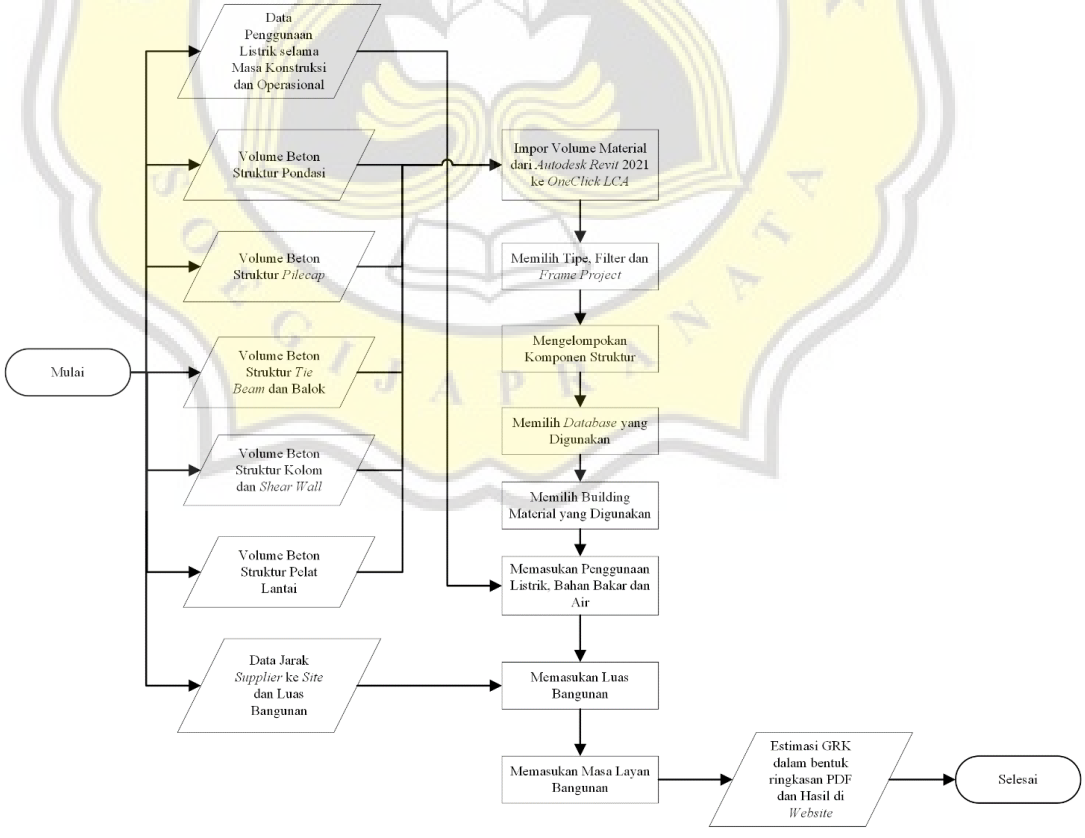
1. BIM *based*-LCA *by* OneClick LCA

Analisis *Life Cycle Assessment* dilakukan dengan menggunakan *OneClick LCA* sebagai alat bantu dalam estimasi LCA berbasis BIM. Volume dan spesifikasi material didapatkan dari pemodelan *Autodesk Revit* 2021 yang dapat langsung diimpor ke *OneClick LCA*. Hasil akhir dari analisis LCA berbasis BIM berupa laporan jumlah emisi gas yang dikeluarkan dari berbagai material yang diperoleh dari fitur *Report*.

Spesifikasi perangkat lunak *OneClick LCA* yang digunakan dalam penelitian adalah sebagai berikut :

a. Nama Program : *OneClick LCA*
b. Versi : 2021
c. Pengembang :
d. Tipe Lisensi : *Student License* (1 tahun)
e. Standar yang digunakan : EN 15978 dan ISO 14040

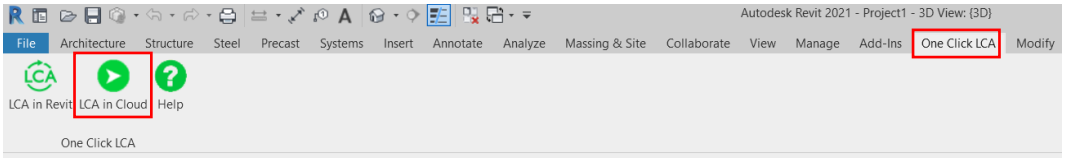
Bagan alir prosedur mengestimasi LCA menggunakan *software OneClick LCA* diperlihatkan pada Gambar 1.



Gambar 1. Bagan Alir Pengaplikasian *OneClick LCA*

Langkah-langkah mengestimasi LCA dengan menggunakan *software OneClick LCA* pada Gambar 1. dapat diuraikan sebagai berikut :

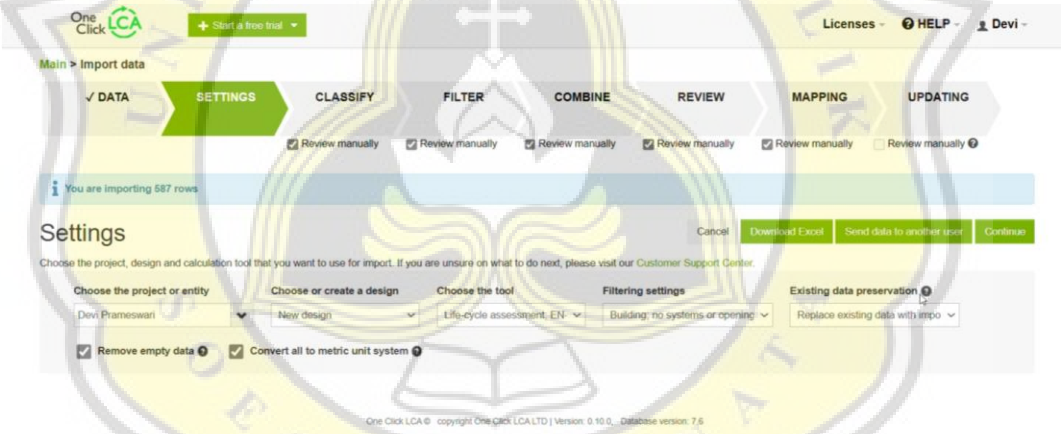
a. Pilih menu *OneClick LCA* pada *Autodesk Revit* kemudian pilih *LCA in Cloud* seperti Gambar 2.



Gambar 2. Menu *OneClick LCA* pada *Autodesk Revit*

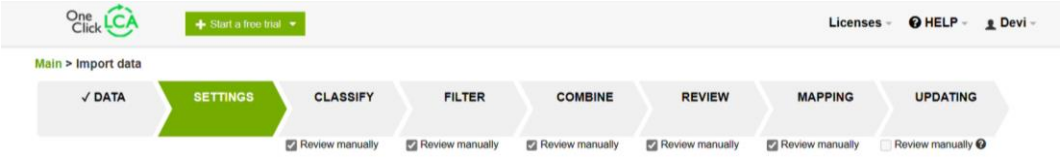
Setelah di pilih menu *LCA in Cloud*, maka akan langsung diarahkan menuju *website* resmi *OneClick LCA*. Proses pengaplikasian *OneClick LCA* dikerjakan seluruhnya di *website* resmi dengan menggunakan data berupa volume dan spesifikasi material yang berhasil diimpor dari *Autodesk Revit*.

b. Setelah masuk ke *website* resmi *OneClick LCA*, akan terlihat tampilan awal *website* resmi *OneClick LCA* dapat diperlihatkan pada Gambar 3.



Gambar 3. Tampilan Awal *Website* Resmi *OneClick LCA*

Setelah masuk ke *website* resmi, akan diarahkan untuk melakukan impor data. Impor data dibagi menjadi 8 tahap yaitu *Data*, *Settings*, *Classify*, *Filter*, *Combine*, *Review*, *Mapping*, dan *Updating* yang dapat diperlihatkan pada Gambar 4.

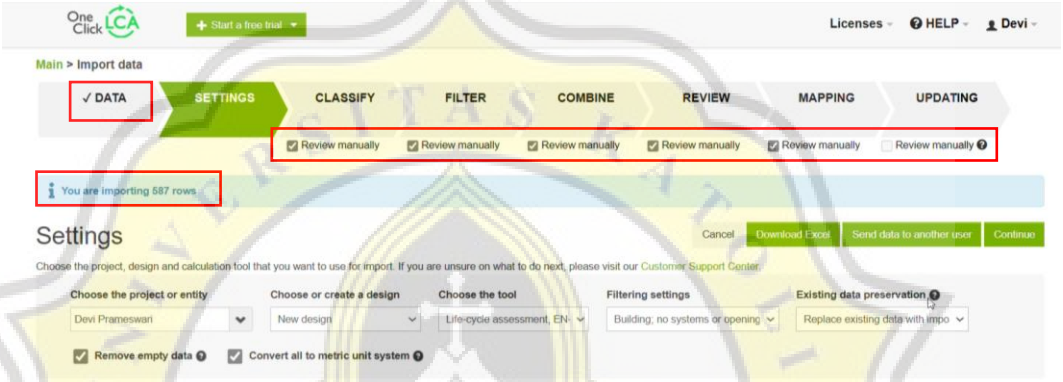


Gambar 4. Tahapan Impor Data

Tahapan impor data dibagi menjadi dua yaitu dilakukan secara otomatis oleh *database* dan diinput secara manual oleh *user* berdasarkan data lapangan. Tahapan-tahapan impor data dapat dijelaskan sebagai berikut :

1. *Data*

   Merupakan tahapan untuk *database* memproses data yang diimpor dari *Autodesk Revit.* Ketika data berhasil diimpor, pada bagian *Data* akan secara otomatis tercentang dan akan memberikan informasi mengenai jumlah data yang berhasil diimpor. Informasi jumlah data yang diimpor dapat diperlihatkan pada Gambar 5.

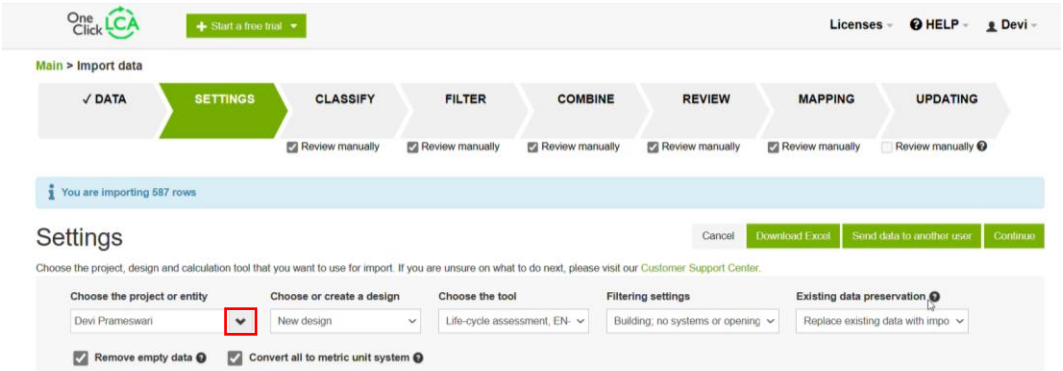


Gambar 5. Jumlah Data yang Berhasil Diimpor

Berdasarkan Gambar 5. diatas, jumlah data yang diimpor dari *Autodesk Revit* adalah sebanyak 587 data yang meliputi spesifikasi material dan tipe-tipe tiap komponen. Kemudian pada pilihan *Review Manually* sebaiknya dicentang semua supaya dapat diperiksa kembali komponen yang digunakan maupun komponen yang tidak digunakan.

2. *Settings*

   Tahap *Settings* merupakan tahapan untuk memasukkan informasi mengenai proyek, jenis proyek, dan alat perhitungan yang ingin digunakan yang dapat diperlihatkan pada Gambar 6.

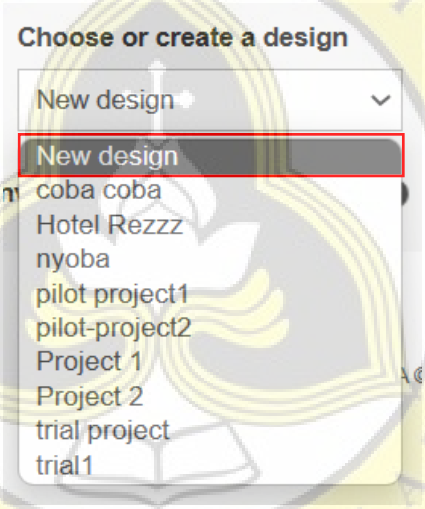


Gambar 6. Tahap *Settings*

Pada tahap *Settings* ini, terdapat beberapa data yang harus diisi dengan cara mengklik tanda panah kebawah dari setiap masing-masing menu. Pada menu *Choose the Project or Entity* dipilih Devi Prameswari, dapat diperlihatkan pada Gambar 7.

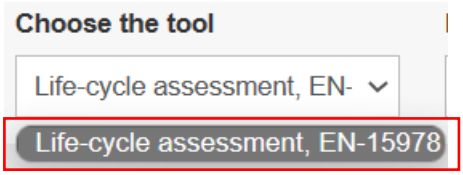
Gambar 7. Menu *Choose the Project or Entity*

Kemudian pada menu *Choose or Create a Design* dipilih *New Design* karena desain yang digunakan adalah desain baru. Menu *Choose or Create a Design* dapat diperlihatkan pada Gambar 8.



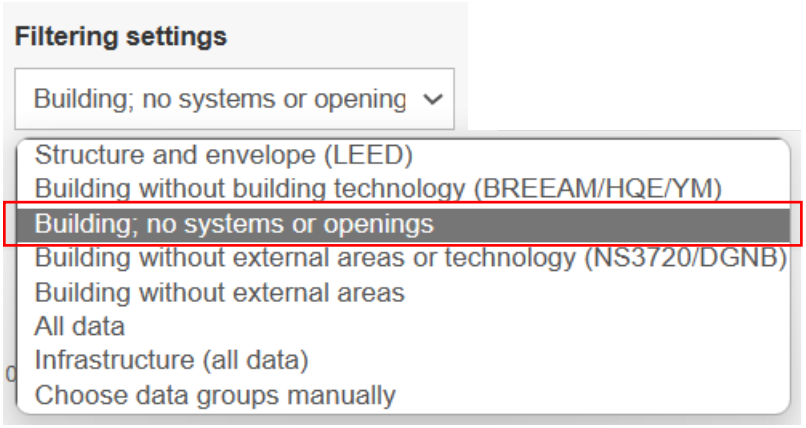
Gambar 8. Menu *Choose or Create a Design*

Pada menu *Choose the Tool* dipilih *Life-cycle Assessment, EN-15978* yang digunakan sebagai acuan dasar dalam estimasi LCA. Menu *Choose the Tool* dapat diperlihatkan pada Gambar 9.



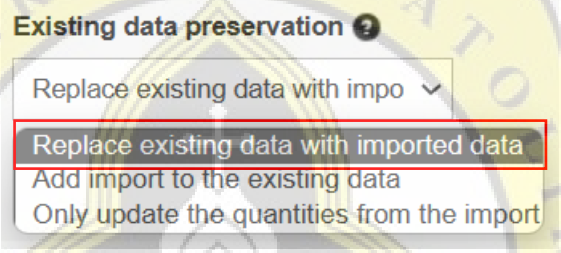
Gambar 9. Menu *Choose the Tool*

Pada menu *Filtering Settings* terdapat beberapa pilihan, pada proyek ini dipilih *Building; No Systems or Openings*. Menu *Filtering Settings* dapat diperlihatkan pada Gambar 10.



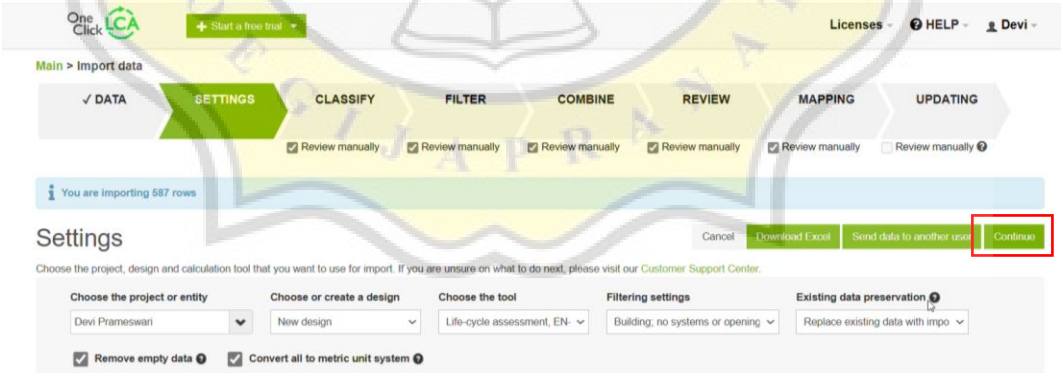
Gambar 10. Menu *Filtering Settings*

Pada menu *Existing Data Preservation* terdapat beberapa pilihan, pada proyek ini digunakan *Replace Existing data With Imported Data*. Menu *Existing Data Preservation* dapat diperlihatkan pada Gambar 11.



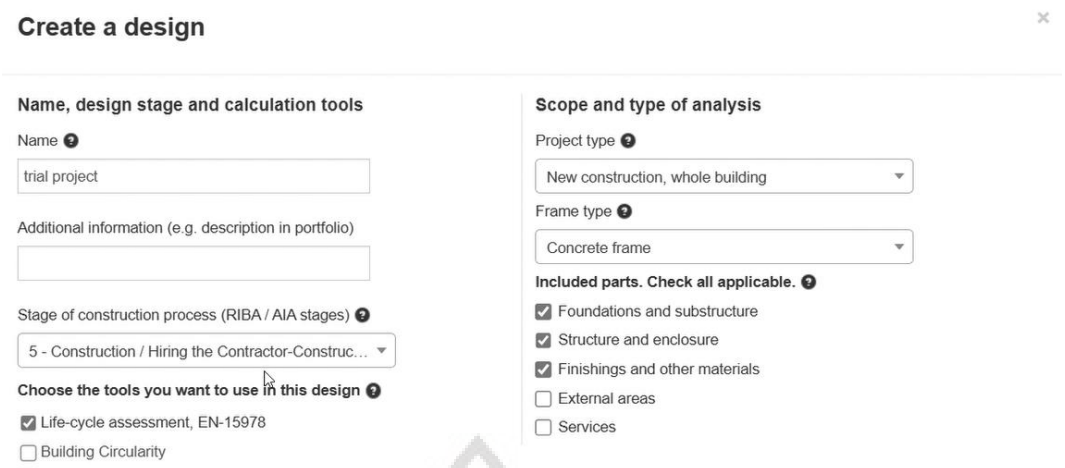
Gambar 11. Menu *Existing Data Preservation*

Setelah semua terisi, klik *Continue* untuk melanjutkan tahapan selanjutnya. *Continue* berada di sebelah ujung kanan yang dapat diperlihatkan pada Gambar 12.



Gambar 12. Klik *Continue*

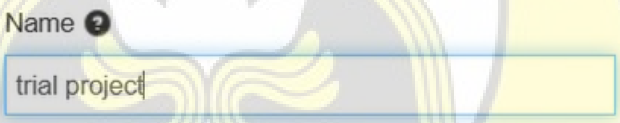
Setelah klik *Continue* akan muncul menu untuk mengisi informasi mengenai proyek yang dapat diperlihatkan pada Gambar 13.



Gambar 13. Menu *Create a Design*

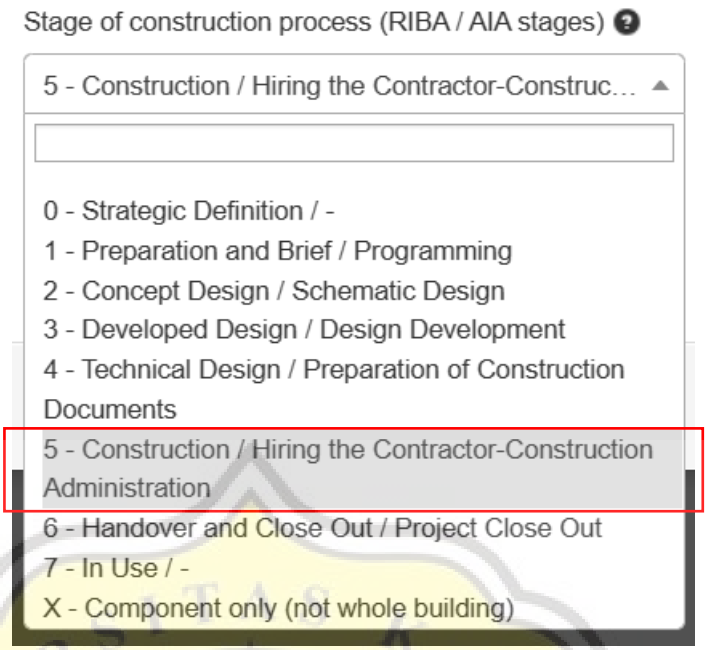
Menu tersebut berisikan nama proyek, deskripsi tambahan mengenai proyek, tahapan dari konstruksi proyek, serta aturan yang digunakan dalam mengestimasi LCA. Menu lainnya adalah untuk menentukan ruang lingkup dan jenis analisis, yang terdiri dari tipe proyek, *frame type* dan pilihan komponen yang akan digunakan.

Pada bagian *Name* diisikan nama proyek. Pada penelitian ini menggunakan nama proyek ”*trial project*” yang dapat dilperlihatkan pada Gambar 14.



Gambar 14.

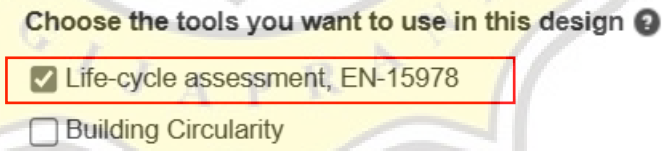
Pada bagian *additional information* apabila tidak diperlukan informasi tambahan, dapat dibiarkan kosong saja. Bagian *stage of construction process* adalah tahapan untuk mengidentifikasi pada tahap konstruksi apa proyek ini berlangsung. Pada penelitian ini digunakan tahapan 5 yaitu *construction or hiring the contractor-construction administration* yang dapat diperlihatkan pada Gambar 15.



Gambar 15. Menu *Stage of Construction Process*

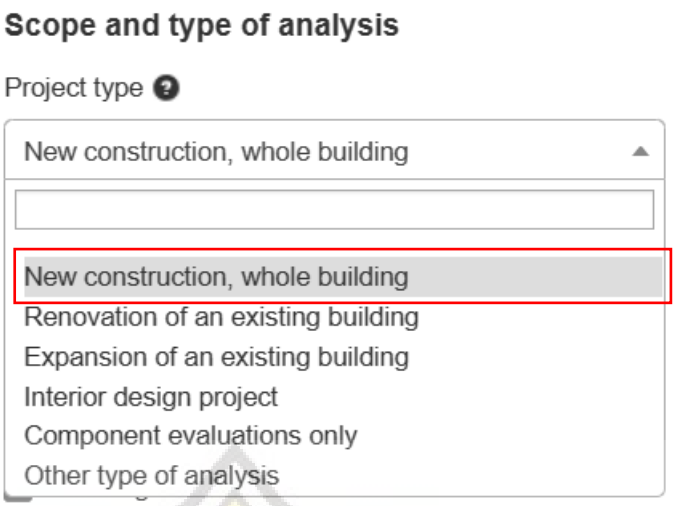
Definisi dari tahap 5 yaitu proses konstruksi dapat melibatkan fabrikasi di luar lokasi dan konstruksi di lokasi. Program konstruksi akan menguraikan kapan setiap jenis konstruksi akan berlangsung, dan tim konstruksi akan menyelesaikan setiap permintaan desain yang muncul.

Kemudian bagian *choose the tools you want to use in this design* adalah pilihan aturan yang digunakan pada desain yang akan dibuat. Pada penelitian ini menggunakan aturan EN-15978 sehingga cukup *checklist* pada pilihan *Life-Cycle Assessment, EN-15978* dan yang lainnya dibiarkan kosong. Pilihan aturan yang digunakan pada penelitian dapat diperlihatkan pada Gambar 16.



Gambar 16. Aturan yang Digunakan Pada Penelitian

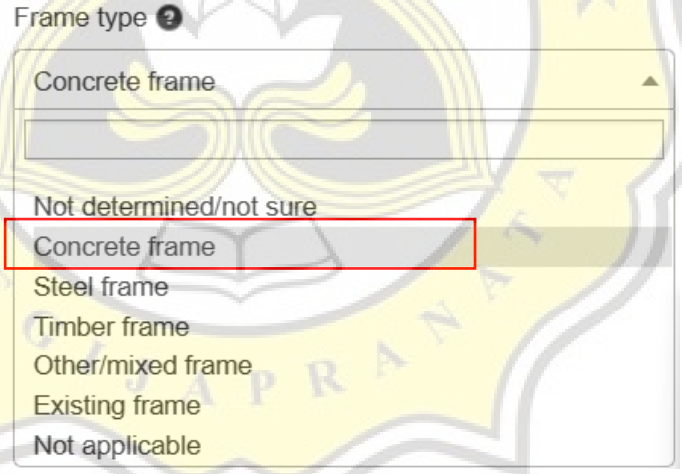
Kemudian pada bagian *scope and type of analysis* terdapat beberapa menu yang wajib diisi yaitu *project type, frame type* dan *included parts*. Pada bagian *project type* terdapat beberapa pilihan yang dapat diperlihatkan pada Gambar 17.



Gambar 17. Menu *Project Type*

Pada penelitian ini dipilih *New Construction, Whole Building* karena akan mendesain bangunan baru secara keseluruhan struktur bangunan.

Kemudian menu *frame type* adalah jenis *frame* yang digunakan pada proyek. Pada penelitian ini dipilih *concrete frame* karena *frame* yang digunakan pada penelitian adalah beton. Pemilihan *frame type* dapat diperlihatkan pada Gambar 18.



Gambar 18. Menu *Frame Type*

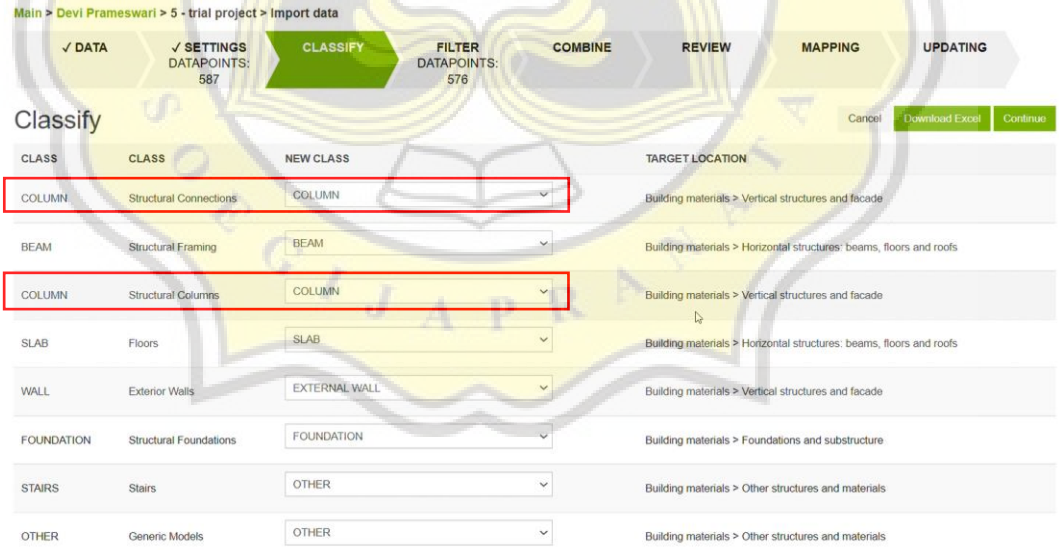
Selanjutnya, bagian *Included Parts* merupakan menu untuk memilih komponen struktur apa saja yang digunakan pada penelitian. Menu *Included Parts* dapat diperlihatkan pada Gambar 19.

Gambar 19. Menu *Included Parts*

Pada penelitian ini, komponen yang digunakan adalah struktur pondasi, *tie beam*, kolom, balok dan pelat lantai sehingga yang dicentang adalah *Foundations and substructure, Structure and enclosure, Finishing and other materials* sedangkan yang lain dibiarkan kosong. Apabila semua sudah lengkap diisi, pilih *Add* pada bagian kanan bawah dan kemudian *database* akan memproses data.

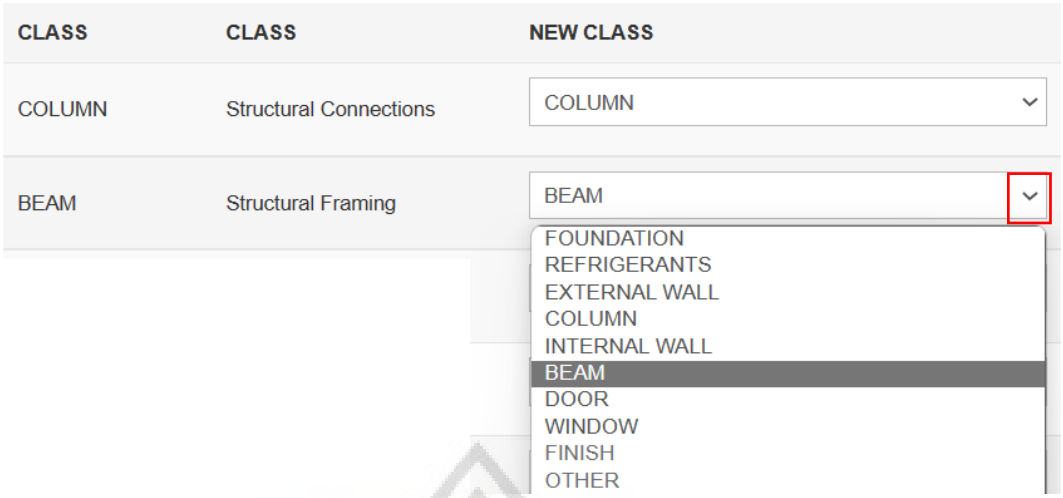
3. *Classify*

Tahap *classify* adalah tahapan untuk mengelompokkan komponen menurut kesamaannya. Contohnya pada *Coloumn* kategori *Structural Connections* dan kategori *Structural Coloumn* akan digabungkan sebagai satu kategori baru yaitu *Coloumn*. Contohnya dapat diperlihatkan pada Gambar 20.



Gambar 20. Tahap *Classify*

Pengelompokan ini dilakukan secara otomatis oleh *database* tetapi apabila ingin mengubah kategori baru, dapat dipilih tanda panah ke bawah untuk mendapatkan pilihan-pilihan kategori baru. Pilihan kategori baru dapat diperlihatkan pada Gambar 21.



Gambar 21. Contoh Pemilihan Kategori Baru

Apabila semua data sudah sesuai dengan kategori yang diinginkan, selanjutnya dapat dipilih *Continue*.

4. *Filter*

Pada tahap *Filter*, dapat dipilih komponen apa saja yang akan digunakan ataupun tidak berdasarkan klasifikasi atau kategori yang sebelumnya sudah dibuat pada tahap *Classify*. Tahap *Filter* dapat diperlihatkan pada Gambar 22.

Gambar 22. Tahap *Filter*

Apabila ada kategori yang tidak ingin digunakan, dapat dihapus centangnya sehingga kategori tersebut tidak akan diproses. Pada penelitian ini hanya menggunakan kategori komponen *Coloumn, Beam, Slab* dan *Foundation* sehingga kategori yang lain dapat dihapus centangnya.

Apabila ingin memeriksa kembali komponen yang ingin dihapus, dapat memilih tanda tanya (?) di samping kategori, kemudian pilih *Delete* untuk

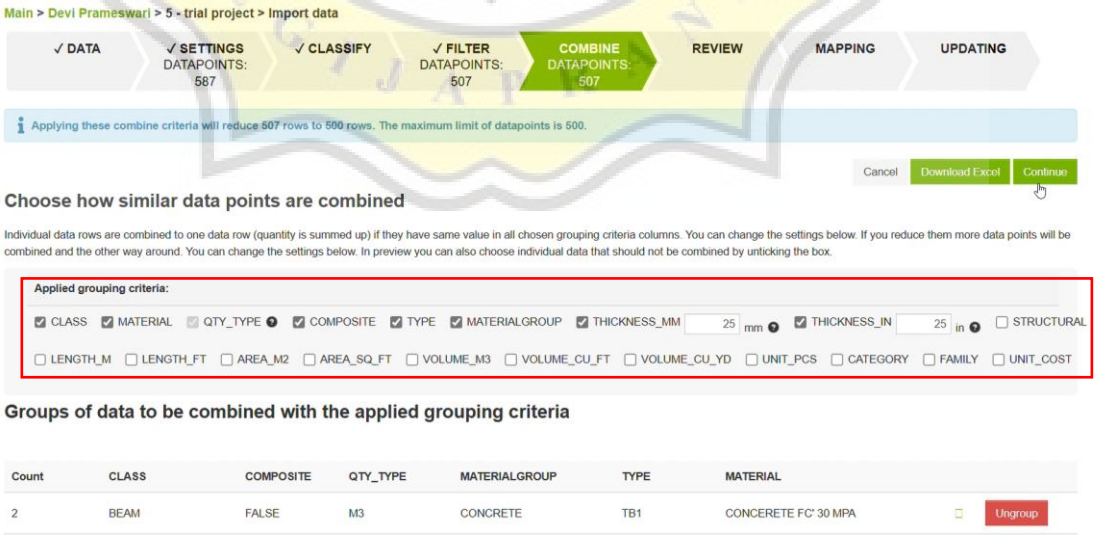
menghapus. Langkah untuk menghapus komponen dapat diperlihatkan pada Gambar 23.

Gambar 23. Menghapus Komponen

Contohnya oada penelitian ini tidak menggunakan komponen baja, sehingga semua komponen yang mengandung baja dapat dihapus. Setelah semua komponen sesuai dengan yang diinginkan, selanjutnya dapat dipilih *Continue* untuk menuju ke tahap selanjutnya.

5. *Combine*

Tahap *Combine* digunakan apabila nilai dari semua komponen dalam kategori pengelompokan sama, maka komponen akan digabungkan menjadi satu baris. Untuk mengelompokkan suatu komponen dapat diatur dengan beberapa kriteria yang telah disediakan dengan cara mencentang atau menghapus centang pada kotak. Tahap *Combine* dapat diperlihatkan pada Gambar 24.

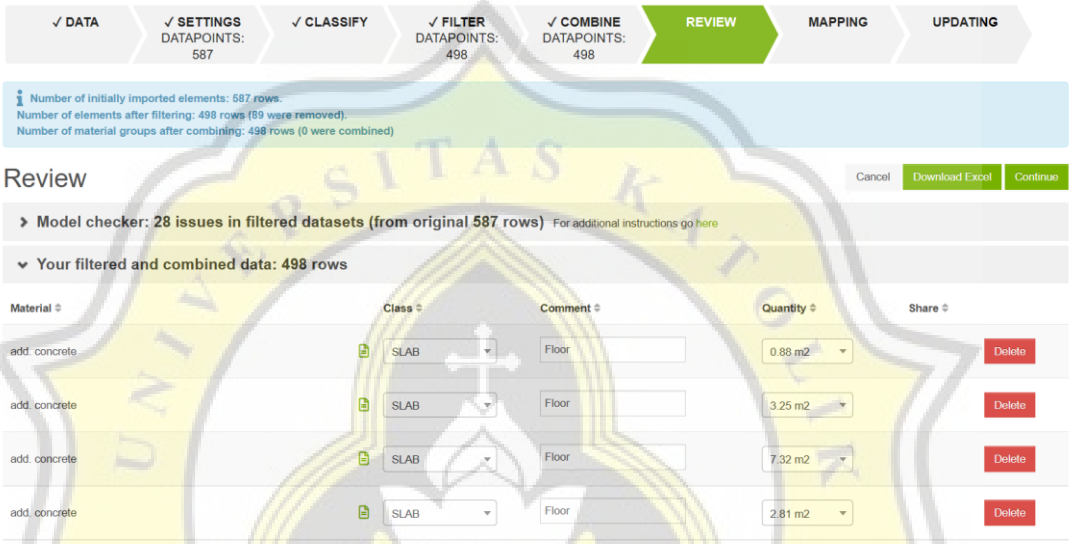


Gambar 24. Tampilan Menu *Combine*

Apabila terdapat data yang tidak bisa digabungkan menjadi satu kelompok, dapat dipilih *Ungroup* sehingga dapat dipilih *Continue* untuk melanjutkan ke tahap berikutnya.

6. *Review*

   Pada tahap *Review* dapat dilakukan pengecekan ulang untuk memastikan komponen yang digunakan maupun tidak. Apabila ingin menghapus material dapat dipilih *Delete* di bagian kanan. Tampilan menu *Review* dapat diperlihatkan pada Gambar 25.

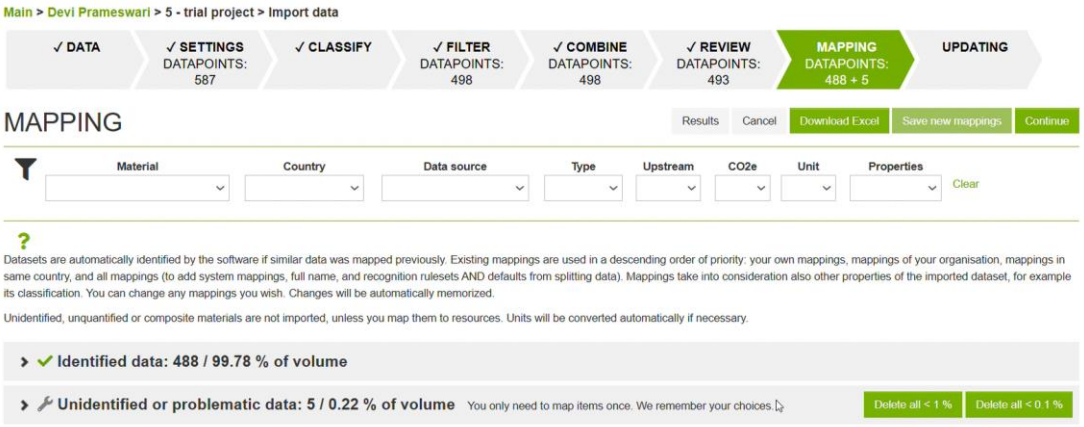


Gambar 25. Tampilan Menu *Review*

Tahap *Review* ini adalah langkah terakhir dalam menentukan komponen atau material yang digunakan sehingga harus dilakukan dengan tepat. Apabila sudah dipastikan material apa saja yang digunakan, dapat dipilih *Continue*.

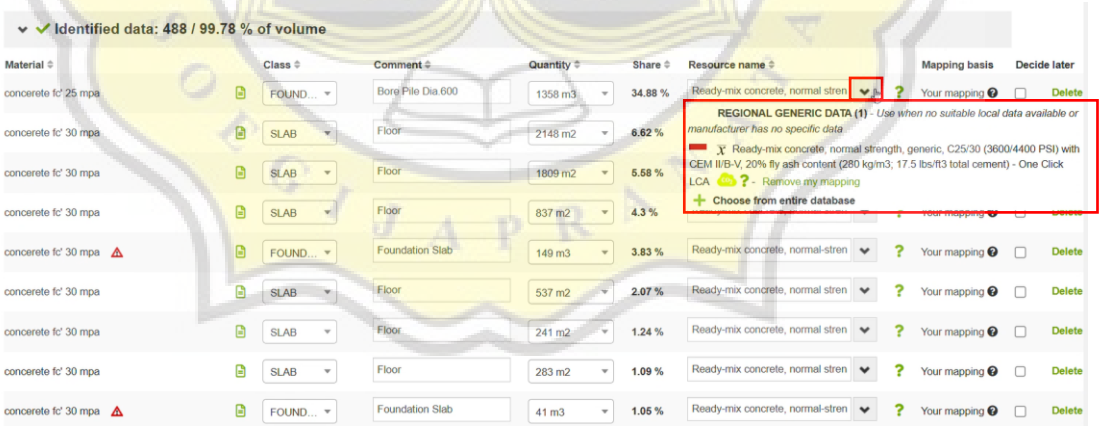
7. *Mapping*

   Tahap *Mapping* digunakan untuk mengidentifikasi data oleh *software*. Pada penelitian ini data yang berhasil diidentifikasi adalah sebanyak 488 data dengan akurasi 99,87%, sedangkan data yang tidak berhasil diidentifikasi adalah sebanyak 5 data dengan akurasi 0,22%. Tampilan menu *Mapping* dapat diperlihatkan pada Gambar 26.



Gambar 26. Tampilan Menu *Mapping*

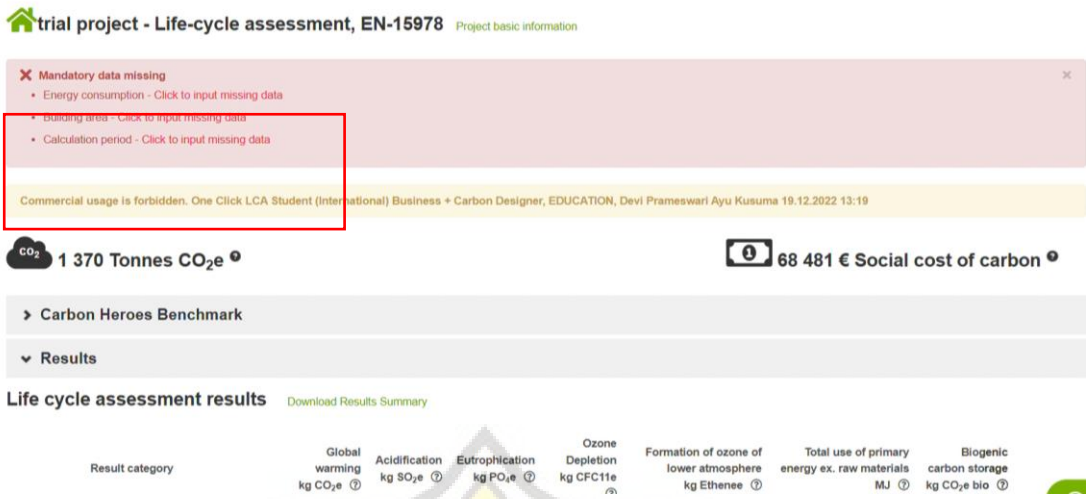
Apabila ingin mengubah data, dapat dipilih tanda panah kebawah untuk menentukan data yang lebih sesuai. Contohnya pada penelitian ini, material beton fc' 25 MPa bahan dasarnya berupa beton *ready-mix* dengan tambahan *fly ash* sebesar 20% dari volume keseluruhan beton. Data tersebut diperoleh dari data proyek yaitu data *concrete mix design*. Beton dengan mutu 25 MPa apabila dikonversi menjadi satuan Psi adalah sekitar 3625 Psi, sehingga dipilih data yang paling mendekati yaitu *Ready-mix concrete, normal strength, generic, C25/30 (3600-4400 PSI) with CEM II/B-V, 20% fly ash content (280 kg/m3; 17,5 lbs/ft3 total cement) – One Click.* Tampilan untuk mengubah data dapat diperlihatkan pada Gambar 27.



Gambar 27. Mengubah Data Pada Tahap *Mapping*

Setelah semua data dapat teridentifikasi, selanjutnya dapat dipilih *Continue* untuk melanjutkan ke tahap berikutnya.

c. Setelah semua impor data sudah selesai diidentifikasi, *software* akan secara otomatis menampilkan hasil estimasi LCA sementara. Tampilan hasil LCA dapat diperlihatkan pada Gambar 28.

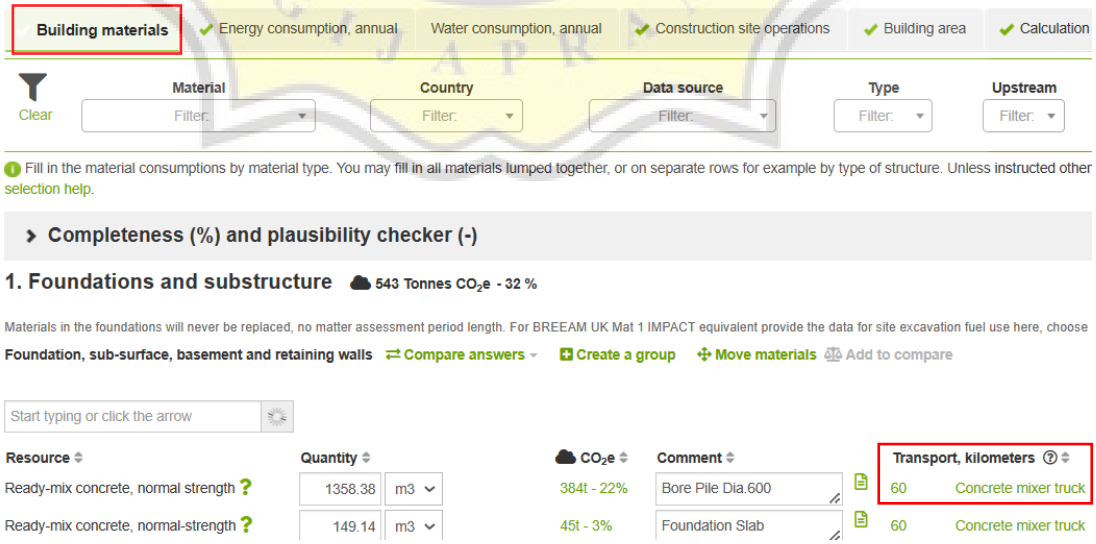


Gambar 28. Tampilan Hasil Sementara Estimasi LCA

Berdasarkan Gambar 28, terdapat tanda *warning* berwarna merah yang berarti bahwa ada beberapa data yang perlu dimasukkan secara manual. Untuk mengisi data-data tersebut, pilih *Click to input missing data*.

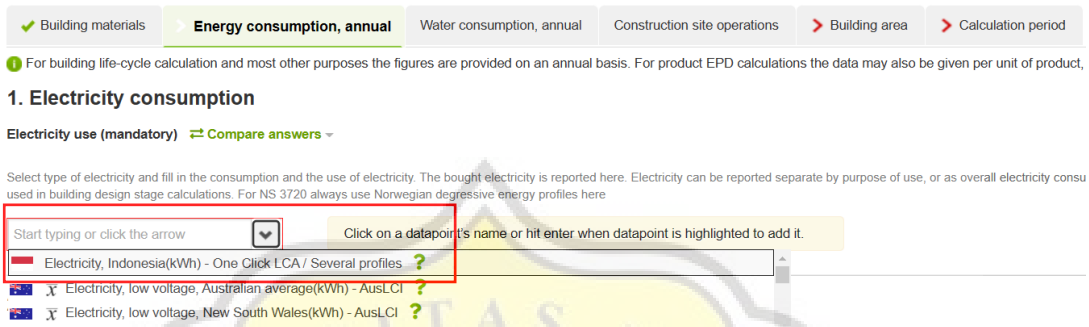
d. Apabila seluruh data sudah diimpor dan berhasil teridentifikasi, tahap selanjutnya adalah melengkapi data yang belum lengkap. Terdapat 6 bagian data yang perlu diisikan secara manual oleh *user* berdasarkan data lapangan, yaitu *Building Materials, Energy Consumption, Water Consumption, Construction Site Operation, Building Area* dan *Calculation Period.*

1. Bagian *Building Materials* digunakan untuk mengecek kembali data kuantitas material yang berhasil diimpor. Pada bagian ini dilakukan juga input data berupa jarak yang ditempuh dan jenis transportasi yang digunakan. Tampilan bagian *Building Materials* dapat diperlihatkan pada Gambar 29.



Gambar 26. Tampilan *Building Materials*

2. Pada bagian *Energy Consumption, annual* terdapat 5 data yaitu *electricity consumption, fuels demand, the consumption of district heating, district cooling* dan *exported energy*. Pada penelitian ini data yang diketahui hanya data *electricity consumption*, sehingga data yang lainnya dibiarkan kosong. Tampilan menu *Electricity Consumption* dapat diperlihatkan pada Gambar 29.



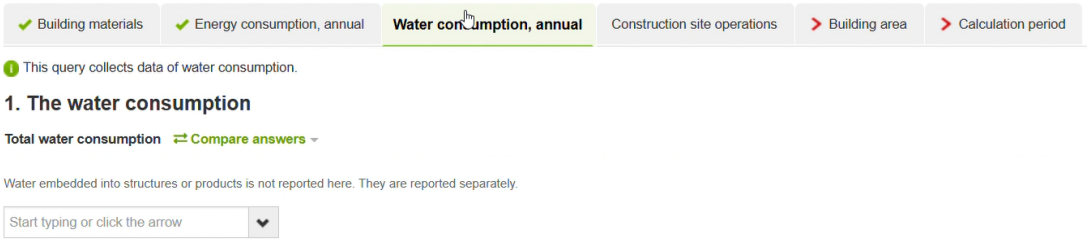
Gambar 29. Tampilan Menu *Electricity Consumption*

Untuk mengisi data konsumsi listrik yang pertama dilakukan adalah memilih tanda panah kebawah. Kemudian akan muncul berbagai pilihan sumber data berdasarkan negara dan satuan yang digunakan. Pada penelitian ini dipilih sumber data dari Indonesia dengan satuan kWH yang dapat diperlihatkan pada Gambar 29.

Gambar 30. Input Data Konsumsi Listrik

Pada bagian *quantity* adalah jumlah listrik yang digunakan selama masa konstruksi dan operasional proyek. Berdasarkan data yang diperoleh dari lapangan, jumlah konsumsi listrik proyek sebesar 7200 kWH, sehingga pada bagian *quantity* diisi 7200. Input data konsumsi listrik proyek dapat diperlihatkan pada Gambar 30. Untuk bagian *fuel demand* tidak diisi karena tidak diketahui jumlah penggunannya. Sedangkan pada bagian *heating* dan *cooling* juga tidak diisi karena proyek tidak menggunakan *heating* maupun *cooling*.

3. Kemudian pada bagian *Water Consumption* dibiarkan kosong karena jumlah air yang digunakan selama masa konstruksi tidak diketahui kuantitasnya. Tampilan *Water Consumption* dapat diperlihatkan pada Gambar 31.



Gambar 31. Tampilan *Water Consumption*

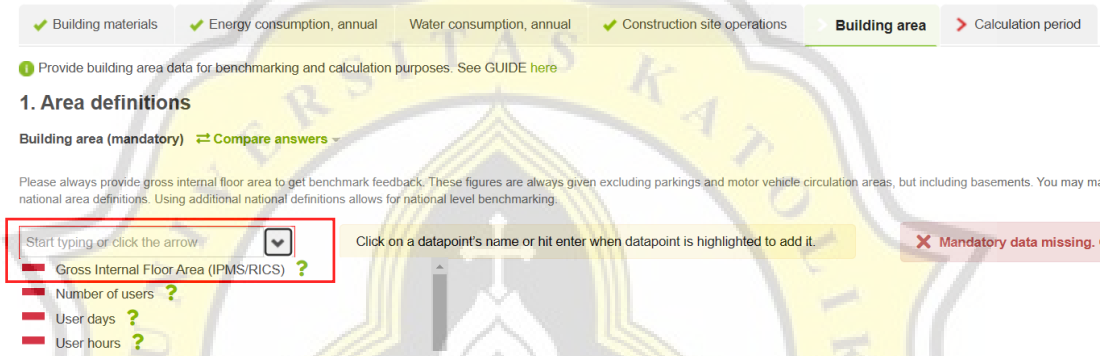
4. Pada bagian *Construction Site Operation* hanya diisi bagian *Energy Use on the Site* yang *Site Electricity Consumption* yang dapat diperlihatkan pada Gambar 32.

Gambar 32. Tampilan *Construction Site Operation*

Pada penelitian ini jumlah konsumsi listrik proyek adalah sebesar 7200 kWH. Untuk mengisi data tersebut, pilih tanda + *Click to input data* kemudian akan muncul tanda panah ke bawah. Pilih tanda panah kebawah kemudian pilih sumber data Indonesia dengan satuan kWH kemudian isi 7200 pada bagian *quantity*. Input data konsumsi listrik proyek dapat diperlihatkan pada Gambar 33.

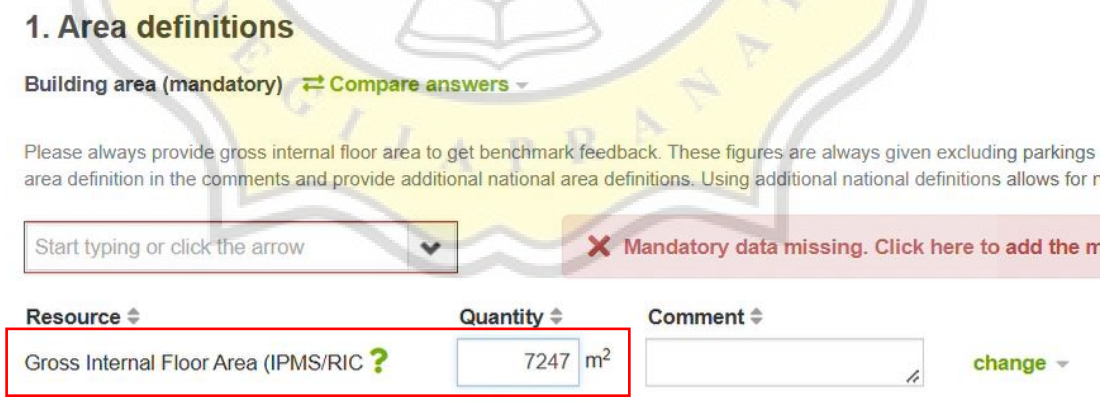
Gambar 33. Tampilan Input Data Listrik Proyek

5. Pada bagian *Building Area*, pilih tanda panah kebawah untuk menentukan *datapoints* yang digunakan. Pada penelitian ini digunakan *Gross Building Area* yang dapat diperlihatkan pada Gambar 34.



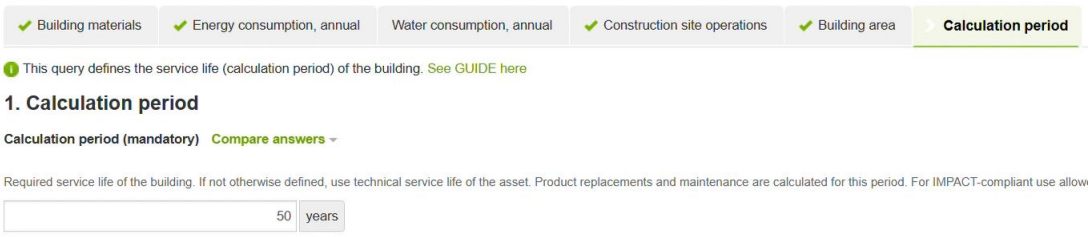
Gambar 34. Tampilan *Building Area*

Kemudian pada bagian *quantity* diisi sesuai dengan luas struktur bangunan yang diperoleh dari data proyek yaitu sebesar 7247 m^2 yang dapat diperlihatkan pada Gambar 35.



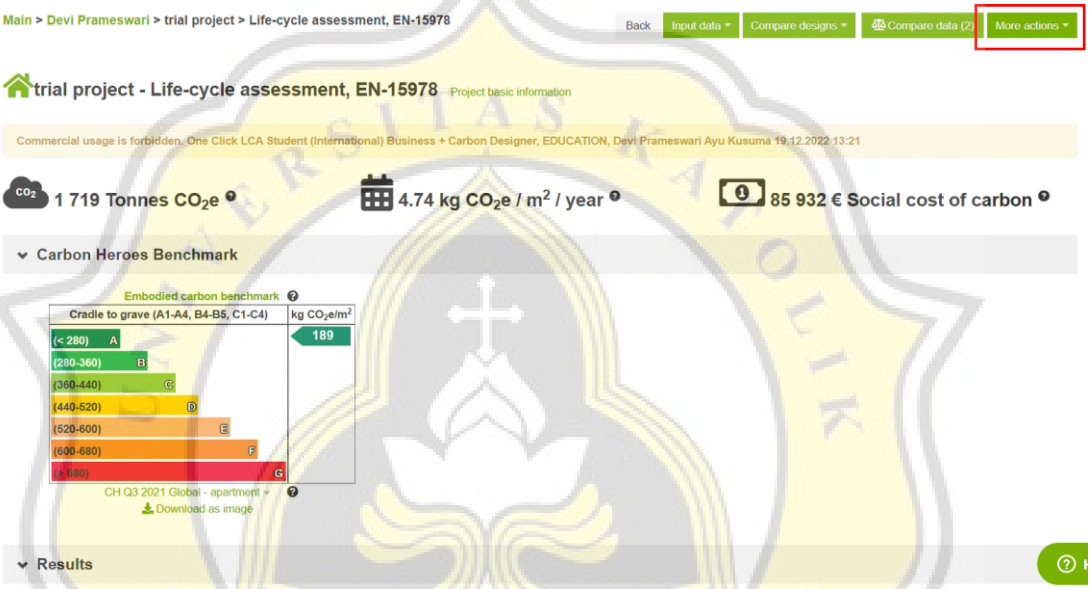
Gambar 35. Tampilan Input *Building Area*

6. Pada bagian *Calculation Period* adalah masa layan bangunan. Pada penelitian ini, masa layan bangunan diasumsikan selama 50 tahun, yang dapat diperlihatkan pada Gambar 36.



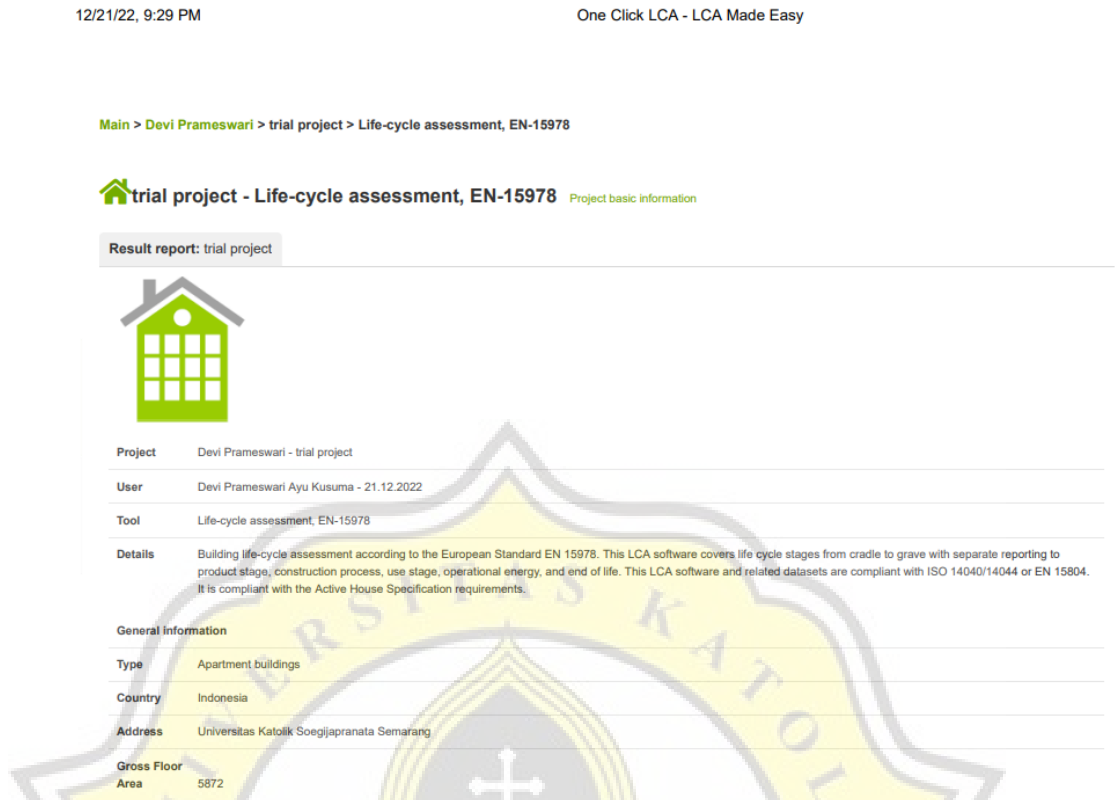
Gambar 36. Tampilan *Calculation Period*

Setelah semua data telah terisi dapat dipilih *Save* kemudian pilih *Result* untuk memperoleh hasil estimasi LCA penelitian ini. kemudian akan muncul tampilan seperti Gambar 37.



Gambar 37. Hasil Estimasi LCA

Untuk mendapatkan *summary* dari seluruh estimasi LCA dapat dipilih *More Action* kemudian pilih *Print.* Laporan dapat diperoleh dalam format PDF yang dapat diperlihatkan pada Gambar 38. dan dapat dilihat dengan lebih jelas pada Lampiran

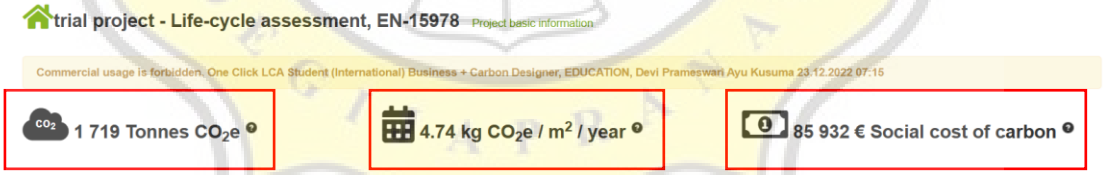


Gambar 38. Tampilan Hasil Estimasi *OneClick LCA*

Hasil *output* dari analisa estimasi LCA dengan menggunakan *software OneClick LCA* dapat diuraikan dan dijelaskan sebagai berikut :

a. *Summary* Awal

Pada bagian tampilan awal, akan muncul beberapa indikator atau lambang yang dapat diperlihatkan pada Gambar 39.



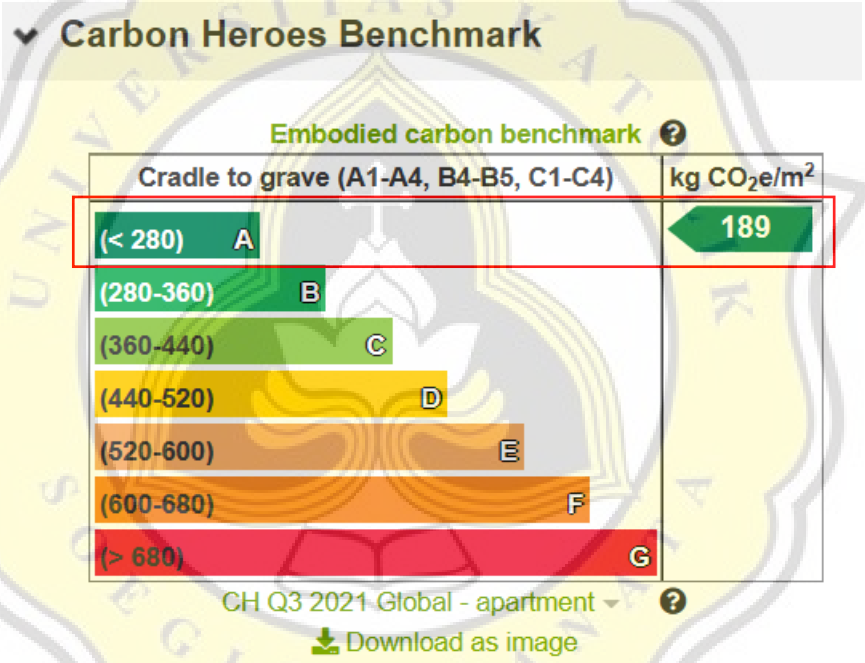
Gambar 39. Tampilan *Summary* Awal

Berdasarkan Gambar 39 terdapat 3 indikator yaitu yang pertama adalah total emisi ekuivalen karbondioksida yang dihasilkan dari proyek, pada proyek ini menghasilkan sekitar 1719 ton emisi ekuivalen karbondioksida. Kemudian yang kedua adalah alat untuk menghitung berapa banyak emisi karbondioksida yang dihasilkan dari proyek berdasarkan waktu penilaian dan ukuran luas lokasi proyek, pada proyek ini menghasilkan sekitar 4,74 kg/m^2/tahun emisi ekuivalen karbondioksida. Selanjutnya yang ketiga adalah biaya karbon per ton yang ditetapkan sebesar 50 dengan satuan mata uang Poundsterling (€). Pada proyek ini,

total biaya karbon yang dihasilkan adalah sebesar 85.932 € yang dikonversi menjadi mata uang rupiah adalah sebesar Rp1.615.251.773,52 (dikonversi pada tanggal 23 Desember 2022).

b. *Carbon Heroes Benchmark*

Carbon Heroes Benchmark atau tolok ukur karbon, memberi informasi mengenai jumlah karbondioksida (CO_2) yang akan dilepaskan oleh berbagai jenis bahan bangunan selama periode 60 tahun. *Carbon heroes benchmark* memperhitungkan bahan yang digunakan, cara pengangkutan bahan, dan berapa lama bangunan akan bertahan. Perhitungan tersebut tidak termasuk dampak lain, seperti CO2 yang dilepaskan saat bahan didaur ulang. *Carbon heroes benchmark* dapat diperlihatkan pada Gambar 40.



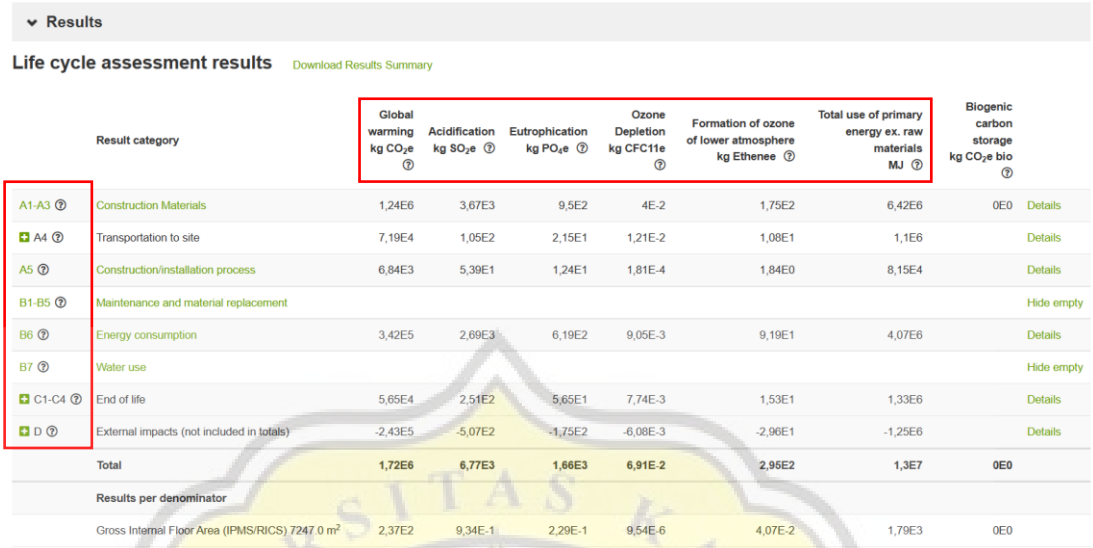
Gambar 40. *Carbon Heroes Benchmark*

Metrik kinerja memiliki tujuh indikator yang mengukur seberapa baik kinerja bangunan relatif terhadap rata-rata untuk jenis bangunan tersebut. Berdasarkan Gambar 40, proyek ini menghasilkan karbondioksida ekuivalen sekitar 189 kg/m^2 sehingga termasuk dalam kategori A.

c. *Life Cycle Assessment Result*

Pada bagian *Life Cycle Assessment Result* ini, terdapat 6 kategori dampak yang dihasilkan dari pelaksanaan proyek konstruksi. Kategori dampak tersebut dinilai berdasarkan tahap-tahap daur hidup proyek (*life cycle stages*) seperti yang

dijelaskan oleh Cao (2017) yang dimuat dalam Subbab 2.1. Hasil LCA dapat diperlihatkan pada Gambar 41.



Results

Life cycle assessment results Download Results Summary

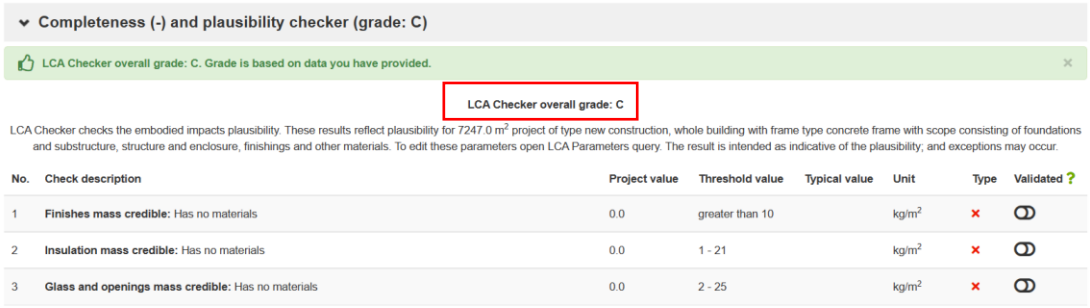
	Result category	Global warming kg CO_2e	Acidification kg SO_2e	Eutrophication kg PO_4e	Ozone Depletion kg CFC11e	Formation of ozone of lower atmosphere kg Ethenee	Total use of primary energy ex. raw materials MJ	Biogenic carbon storage kg CO_2e bio	
A1-A3	Construction Materials	1,24E6	3,67E3	9,5E2	4E-2	1,75E2	6,42E6	0E0	Details
A4	Transportation to site	7,19E4	1,05E2	2,15E1	1,21E-2	1,08E1	1,1E6		Details
A5	Construction/installation process	6,84E3	5,39E1	1,24E1	1,81E-4	1,84E0	8,15E4		Details
B1-B5	Maintenance and material replacement								Hide empty
B6	Energy consumption	3,42E5	2,69E3	6,19E2	9,05E-3	9,19E1	4,07E6		Details
B7	Water use								Hide empty
C1-C4	End of life	5,65E4	2,51E2	5,65E1	7,74E-3	1,53E1	1,33E6		Details
D	External impacts (not included in totals)	-2,43E5	-5,07E2	-1,75E2	-6,08E-3	-2,96E1	-1,25E6		Details
	Total	**1,72E6**	**6,77E3**	**1,66E3**	**6,91E-2**	**2,95E2**	**1,3E7**	**0E0**	
	Results per denominator								
	Gross Internal Floor Area (IPMS/RICS) 7247.0 m^2	2,37E2	9,34E-1	2,29E-1	9,54E-6	4,07E-2	1,79E3	0E0	

Gambar 41. Hasil LCA

Berdasarkan Gambar 41, terdapat 6 kategori dampak yaitu yang pertama *Global Warming* (CO_2e) yang merupakan indikator ketika jumlah gas rumah kaca di atmosfer meningkat, suhu atmosfer bumi menghangat dan menyebabkan perubahan iklim. Kemudian yang kedua adalah *Acidification* (SO_2e) yang menyebabkan zat pengasaman bereaksi dengan air dan membentuk asam. Sulfat membuat tanaman sulit tumbuh dan menyebabkannya membusuk. Selanjutnya yang ketiga adalah *Eutrophication* (PO_4e) terjadi ketika kadar fosfat berlebihan yang menyebabkan pertumbuhan tanaman yang tidak diinginkan dalam ekosistem, seperti ledakan alga yang dapat membunuh ikan. Kemudian yang keempat adalah *Ozone Depletion* ($CFC_{11}e$) yaitu penipisan lapisan ozon stratosfer yang melindungi flora dan fauna dari radiasi UV-A dan UV-B matahari yang berbahaya. *Formation of Ozone Lower Athmospere* (etana) yaitu pembentukan ozon di atmosfer bagian bawah yang dapat membahayakan sistem pernapasan. Kemudian yang terakhir adalah *Total Use of Primary Energy* (*raw material*) yaitu jumlah penggunaan bahan baku.

d. *Completeness* (-) *and Plausibility Checker*

Completeness and plausibility checker berfungsi untuk memeriksa kelengkapan dan kelayakan. Hasilnya mungkin tidak selalu akurat, tetapi merupakan indikasi yang masuk akal tentang apa yang dapat dilakukan. Pemeriksa LCA memeriksa kemungkinan dampak yang diwujudkan yang dapat diperlihatkan pada Gambar 42.



Completeness (-) and plausibility checker (grade: C)

LCA Checker overall grade: C. Grade is based on data you have provided.

LCA Checker overall grade: C

LCA Checker checks the embodied impacts plausibility. These results reflect plausibility for 7247.0 m^2 project of type new construction, whole building with frame type concrete frame with scope consisting of foundations and substructure, structure and enclosure, finishings and other materials. To edit these parameters open LCA Parameters query. The result is intended as indicative of the plausibility; and exceptions may occur.

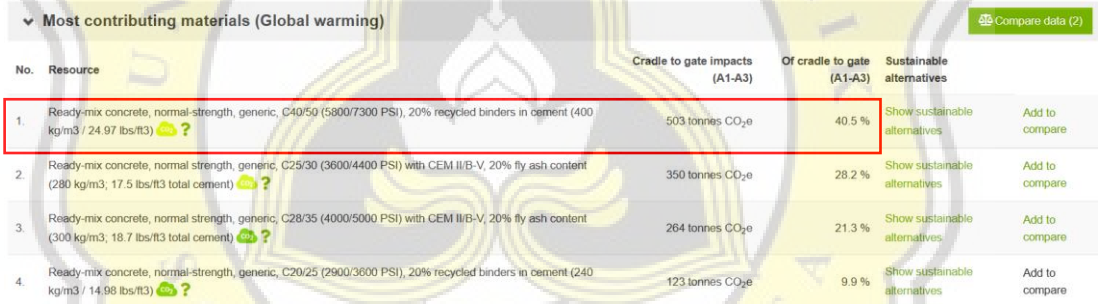
No.	Check description	Project value	Threshold value	Typical value	Unit	Type	Validated ?
1	**Finishes mass credible:** Has no materials	0.0	greater than 10		kg/m^2	×	
2	**Insulation mass credible:** Has no materials	0.0	1 - 21		kg/m^2	×	
3	**Glass and openings mass credible:** Has no materials	0.0	2 - 25		kg/m^2	×	

Gambar 42. *Completeness and plausibility checker*

Hasil ini mencerminkan kelayakan suatu proyek seluas 7247 m^2 yang mencakup pondasi dan substruktur, struktur, *finishing* dan material lainnya. Berdasarkan Gambar 42 diperoleh hasil bahwa proyek ini termasuk dalam kelas C.

e. *Most Contributing Materials (Global Warming)*

Merupakan hasil analisis LCA yang menunjukkan penggunaan bahan baku apa yang menghasilkan karbondioksida yang berkontribusi tinggi terhadap pemanasan global. Material yang paling berpengaruh terhadap pemanasan global dapat diperlihatkan pada Gambar 43.



Most contributing materials (Global warming)

Compare data (2)

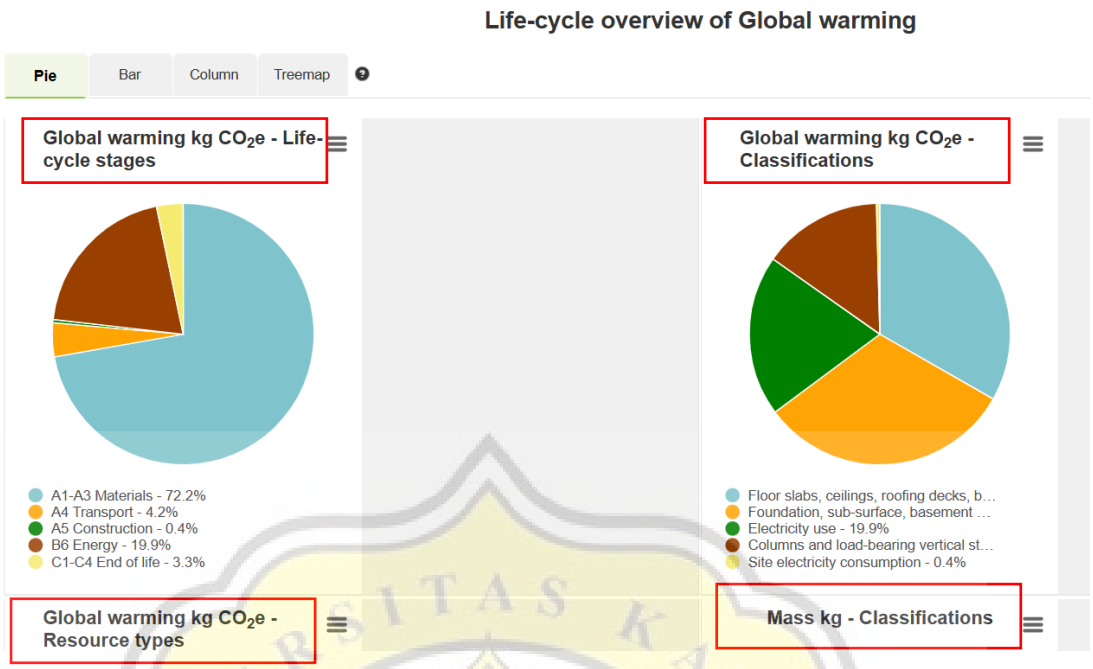
No.	Resource	Cradle to gate impacts (A1-A3)	Of cradle to gate (A1-A3)	Sustainable alternatives	
1.	Ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 20% recycled binders in cement (400 kg/m3 / 24.97 lbs/ft3)	503 tonnes CO_2e	40.5 %	Show sustainable alternatives	Add to compare
2.	Ready-mix concrete, normal strength, generic, C25/30 (3600/4400 PSI) with CEM II/B-V, 20% fly ash content (280 kg/m3; 17.5 lbs/ft3 total cement)	350 tonnes CO_2e	28.2 %	Show sustainable alternatives	Add to compare
3.	Ready-mix concrete, normal strength, generic, C28/35 (4000/5000 PSI) with CEM II/B-V, 20% fly ash content (300 kg/m3; 18.7 lbs/ft3 total cement)	264 tonnes CO_2e	21.3 %	Show sustainable alternatives	Add to compare
4.	Ready-mix concrete, normal-strength, generic, C20/25 (2900/3600 PSI), 20% recycled binders in cement (240 kg/m3 / 14.98 lbs/ft3)	123 tonnes CO_2e	9.9 %	Show sustainable alternatives	Add to compare

Gambar 43. *Most Contributing Materials (Global Warming)*

Berdasarkan Gambar 43 dapat diperlihatkan bahwa bahan baku yang paling berpengaruh bagi pemanasan global dari proyek ini adalah penggunaan *ready-mix concrete, normal-strength, generic, C40/50 (5800/7300 PSI), 20% recycled binders in cement (400 kg/m^3/24,97 lbs/ft^3)* yang menghasilkan karbondioksida sebanyak 503 ton atau sekitar 40,5% dari keseluruhan bahan baku yang digunakan.

f. *Graphs*

Merupakan menu yang menyediakan hasil analisa LCA dalam bentuk diagram lingkaran, grafik batang, diagram batang dan *treemap* yang dapat diperlihatkan pada Gambar 44.

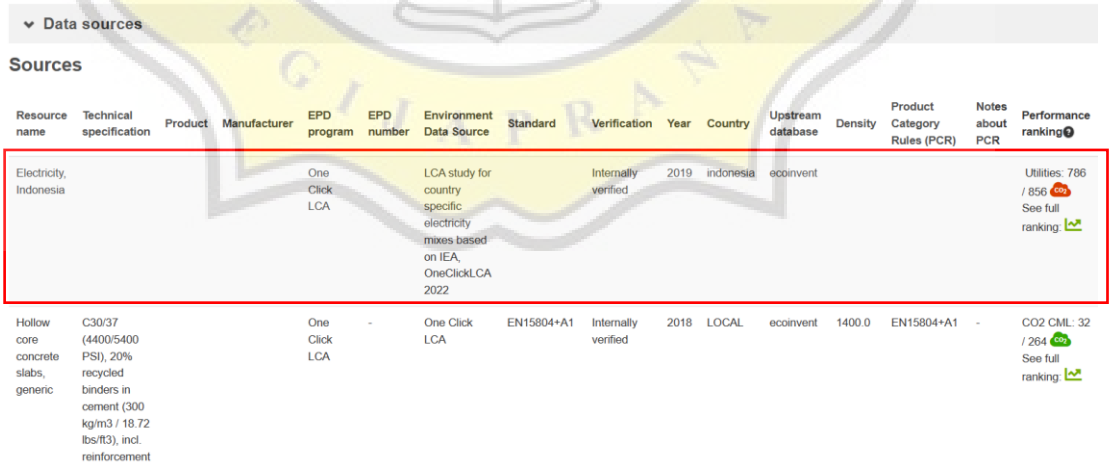


Gambar 44. Hasil Analisa LCA dalam Diagram Lingkaran

Terdapat 4 grafik yang akan muncul yaitu penyebab pemanasan global berdasarkan tahap daur hidup (*life cycle stages*), penyebab pemanasan global berdasarkan klasifikasi, penyebab pemanasan global berdasarkan bahan baku material dan yang terakhir adalah berat total material berdasarkan klasifikasi.

g. *Data Sources*

Merupakan kumpulan sumber data yang digunakan dalam analisa LCA oleh *OneClick LCA* berdasarkan jenis material yang digunakan, yang dapat diperlihatkan pada Gambar 45.



Gambar 45. *Data Source*

Berdasarkan Gambar 45 menunjukan bahwa sumber data yang digunakan untuk listrik proyek menggunakan data dari negara Indonesia tahun 2019.

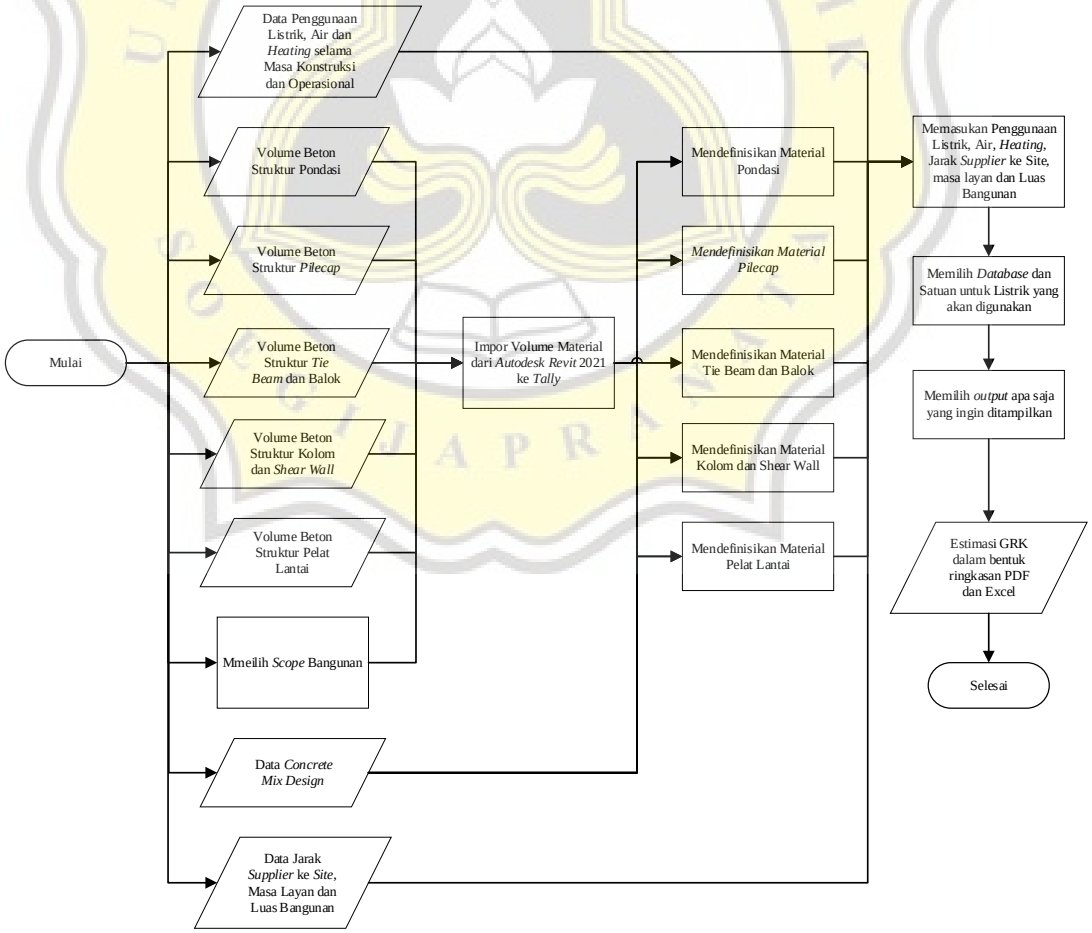
2. BIM-*based* LCA by *Tally*

Analisis *Life Cycle Assessment* dilakukan dengan menggunakan *Tally* sebagai alat bantu dalam estimasi LCA berbasis BIM. Volume dan spesifikasi material didapatkan dari pemodelan *Autodesk Revit* 2021 yang dapat langsung terhubung dengan *Tally*. Hasil akhir dari analisis LCA berbasis BIM berupa laporan jumlah emisi gas yang dikeluarkan dari berbagai material yang diperoleh dari fitur *Report*.

Spesifikasi perangkat lunak *Tally* yang digunakan dalam penelitian adalah sebagai berikut :

a. Nama Program : *Tally*
b. Versi : 2021
c. Pengembang :
d. Tipe Lisensi : *Student License* (1 tahun)
e. Standar yang digunakan : EN 15978 dan ISO 14040

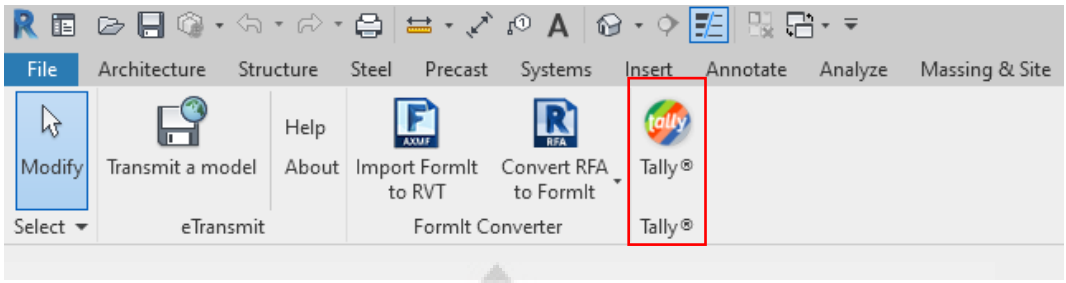
Prosedur estimasi LCA dengan menggunakan *Tally* diperlihatkan pada Gambar 1.



Gambar 1. Prosedur Estimasi Dengan *Tally*

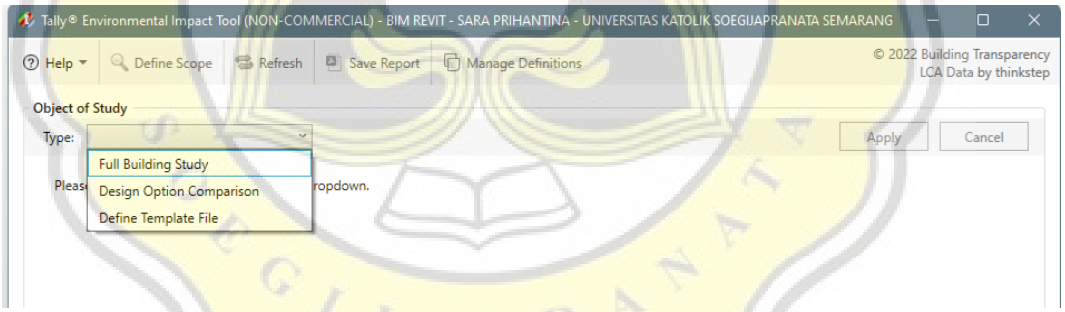
Langkah-langkah pengestimasian LCA dengan menggunakan *Tally* pada Gambar 1 diuraikan sebagai berikut :

a. Pilih menu *Add-ins* kemudian pilih *Tally* seperti pada Gambar 3.36.



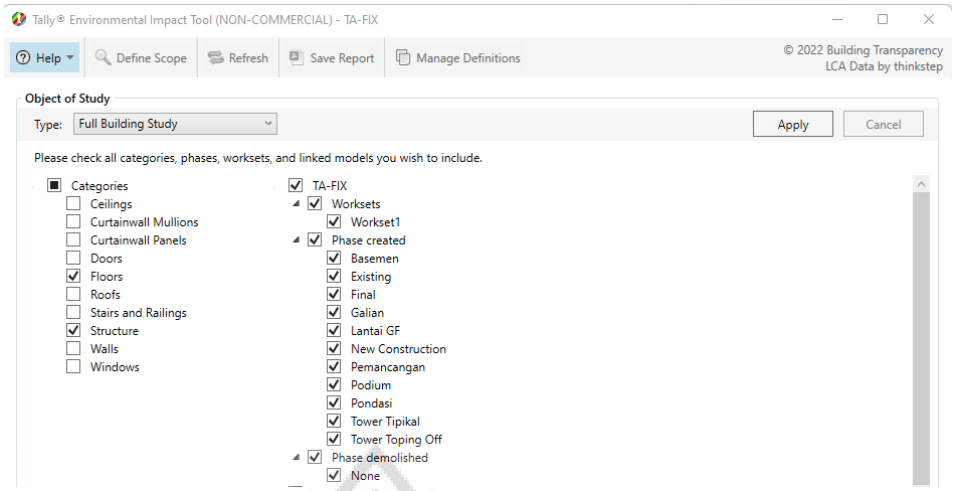
Gambar 2. Menu *Add-ins*

b. Setelah muncul menu seperti Gambar 3.37, klik *type* dan pilih tipe *Full Building Study*. Terdapat 3 tipe *Object of Study* yaitu *Full Building Study*, *Design Option Comparison* dan *Define Template File*. *Full Building Study* digunakan menganalisa bangunan secara keseluruhan, *Design Option Comparison* digunakan untuk membandingkan material pada komponen suatu bangunan sedangkan *Define Template File* digunakan jika pengguna sudah memiliki *template* sendiri. Tipe *object of study* diperlihatkan pada Gambar 3. Pada penelitian ini, *object of study* yang digunakan adalah *full building study*.



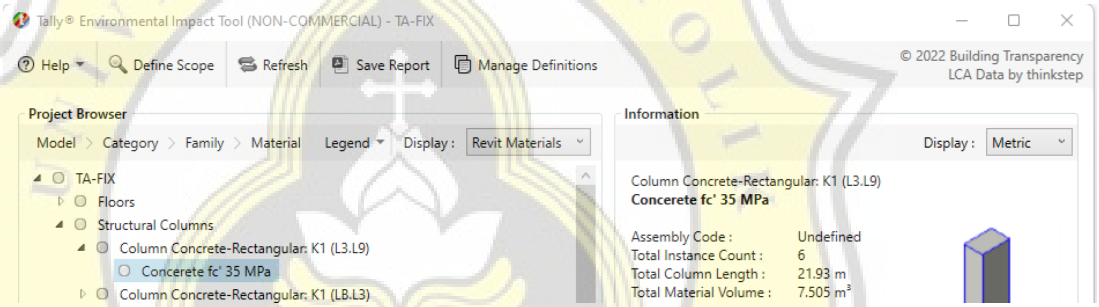
Gambar 3. Tipe *Object of Study*

c. Setelah itu pilih kategori atau bagian-bagian bangunan yang hendak dianalisis dan fase bangunan lalu klik *apply*. Tampilan Fase dan Kategori Bangunan dapat diperlihatkan pada Gambar 4.



Gambar 4. Kategori *Object of Study*

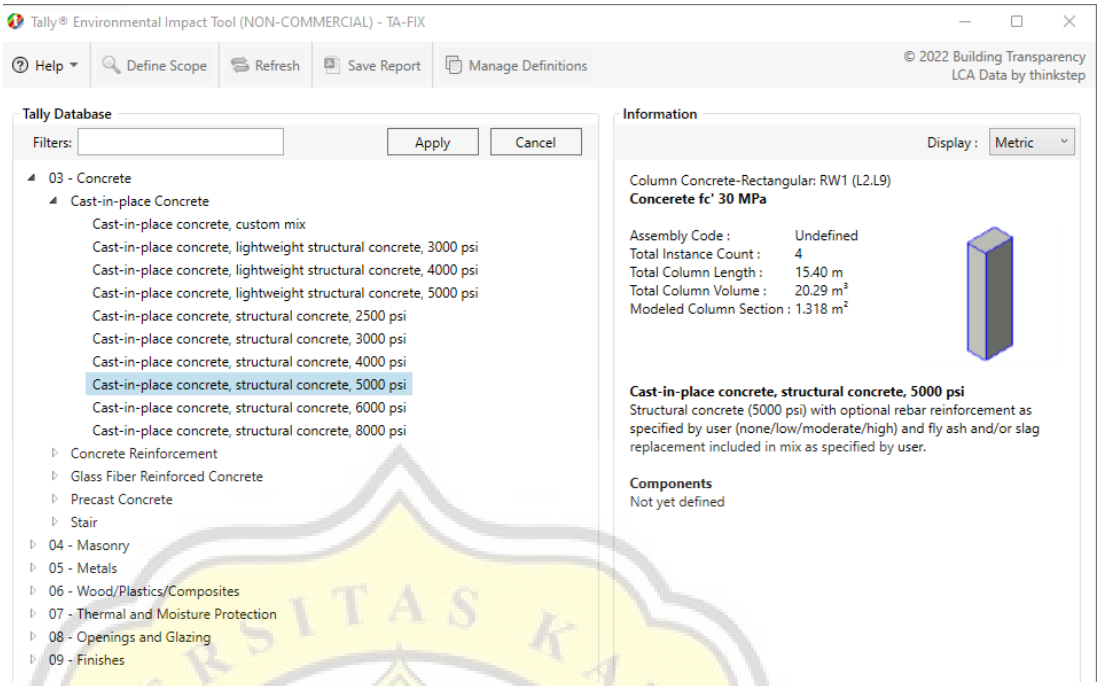
d. Kemudian akan muncul bagian-bagian pada bangunan, tipe dan juga material yang dipakai oleh komponen tersebut. Menu komponen dan material bangunan dapat diperlihatkan pada Gambar 5.



Gambar 5. *Project Browser*

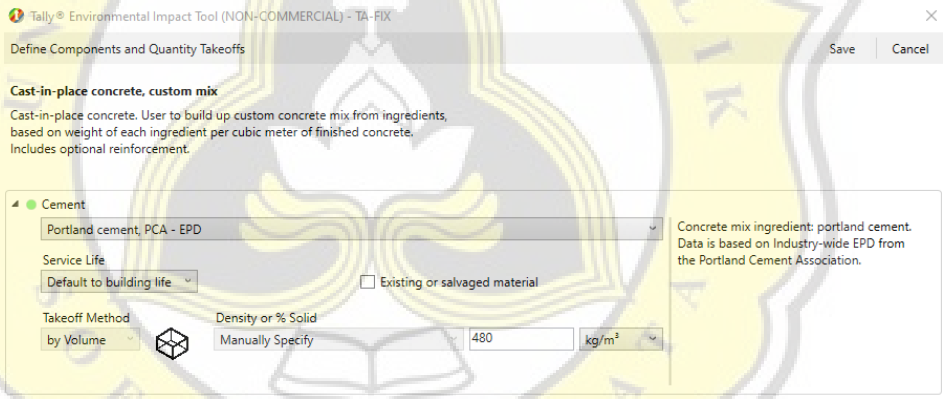
e. Setelah itu pilih jenis material yang akan digunakan lalu klik kanan dan pilih *edit definition*.

f. Kemudian pilih concrete dan pilih jenis beton yang akan digunakan. Untuk beton dengan mutu 25 MPa dan 35 MPa yang memiliki *concrete mix design*, dipilih *custom mix*.

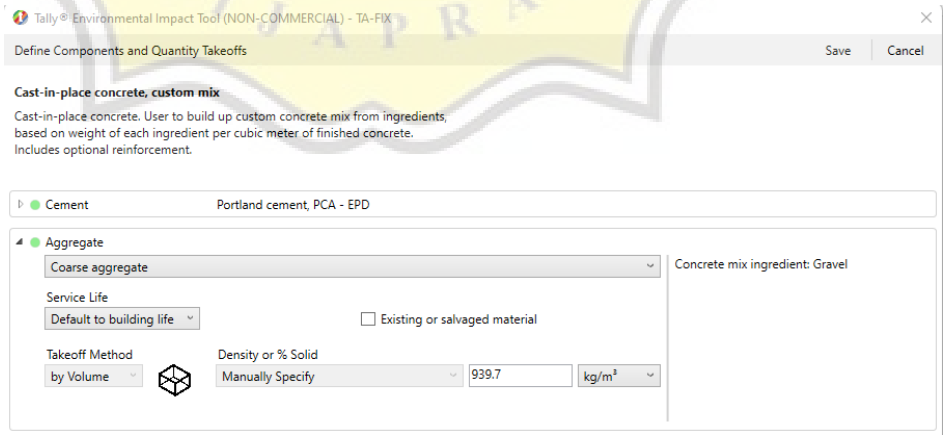


Gambar 6. Menu *Concrete*

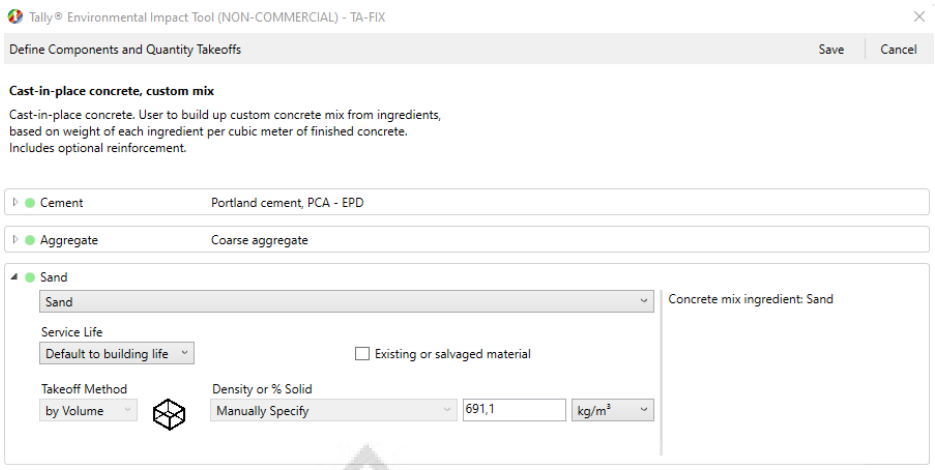
Berikut adalah contoh pengisian untuk beton mutu 35 MPa.



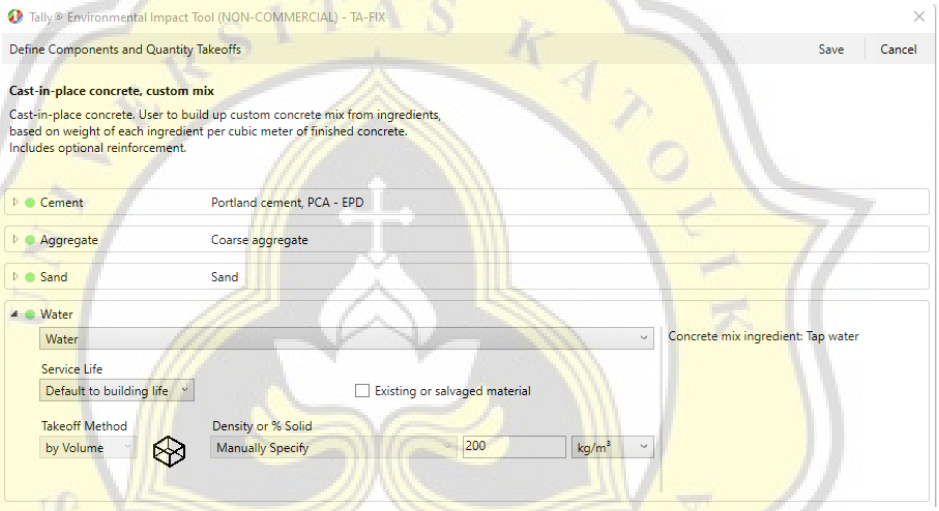
Gambar 7. Pengisian Semen



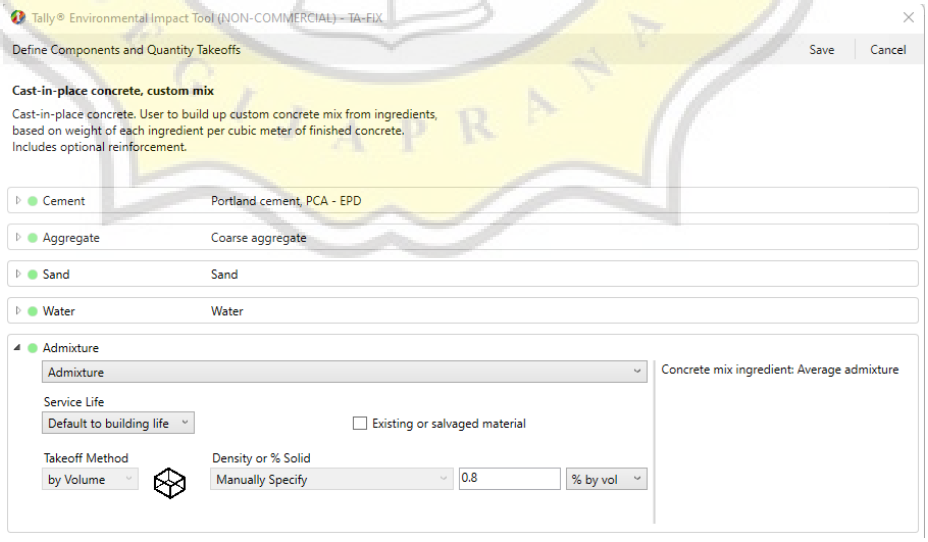
Gambar 8. Pengisian Agregat Kasar



Gambar 9. Pengisian Agregat Halus

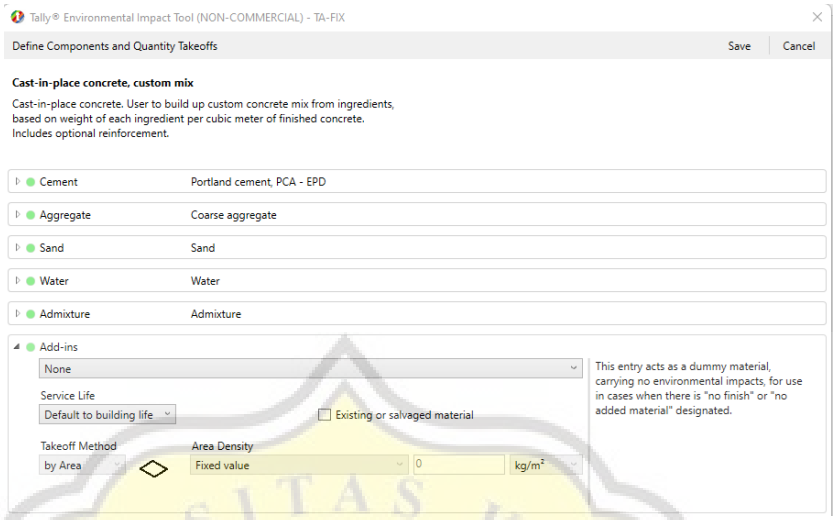


Gambar 10. Pengisian Air

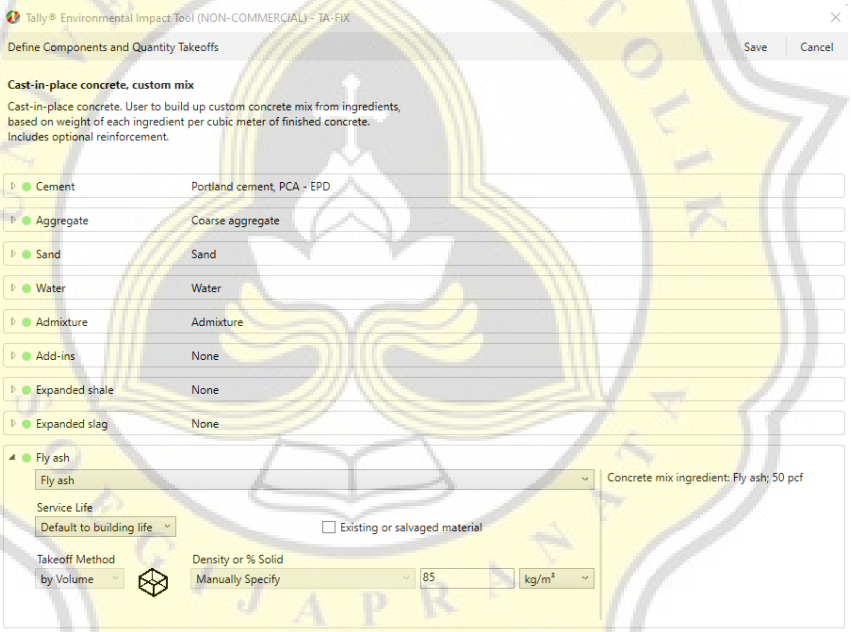


Gambar 11. Pengisian *Admixture*

Untuk *Add-ins*, *Expanded Shale*, *Expanded Slag* dan *Glass Fiber* yang tidak terdapat dalam *concrete mix design*, dapat dipilih *none*.

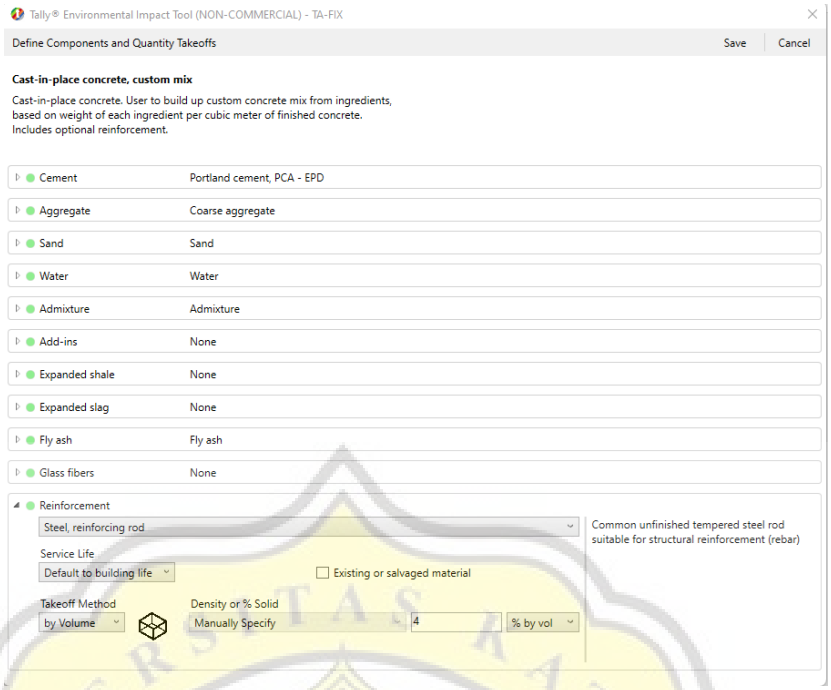


Gambar 12. Pengisian *Add-ins*



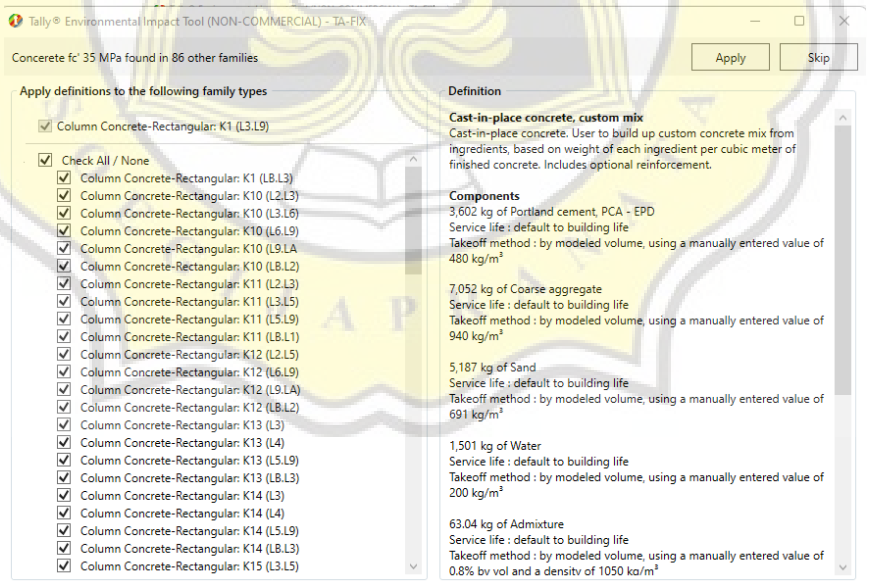
Gambar 13. Pengisian *Fly Ash*

Tulangan yang digunakan diasumsikan sebesar 4% dari volume beton sesuai dengan SNI 2847 – 2019 yang menyatakan bahwa tulangan maksimal yang digunakan pada beton bertulang tidak boleh melebihi 4%.



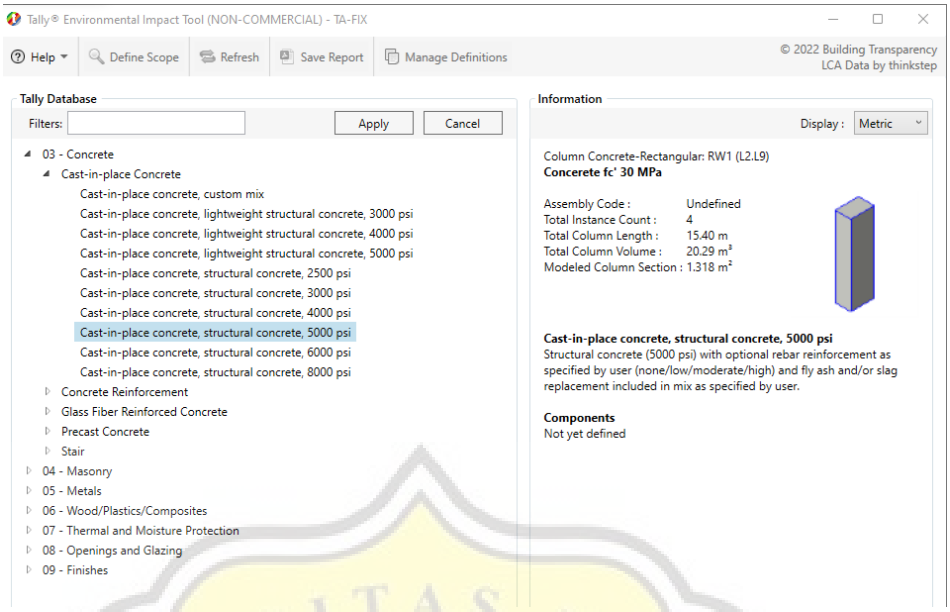
Gambar 14. Pengisian Tulangan

Setelah semua pengisian selesai, dapat diklik save dan akan muncul menu seperti Gambar apabila komponen struktur lain memiliki mutu material yang sama. Komponen dengan material yang sama dapat langsung terisi dengan mix design yang sudah dimasukan tadi.



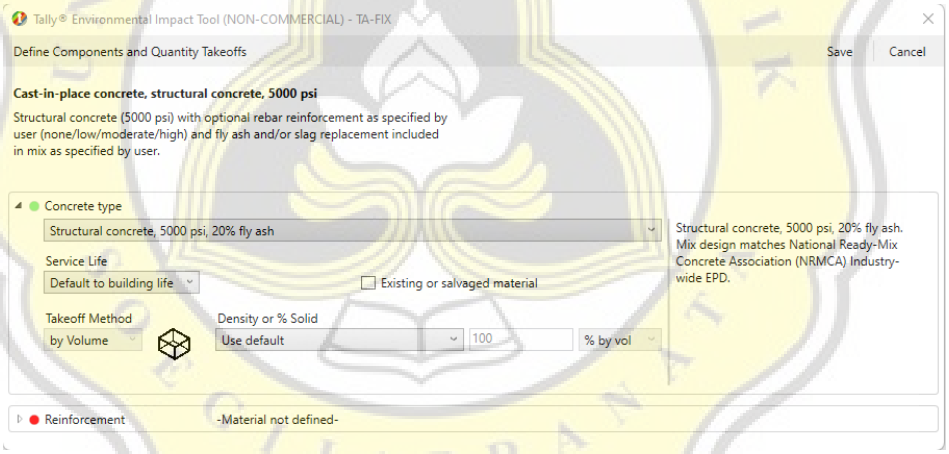
Gambar 15. Pengisian Komponen Struktur Dengan Mutu yang Sama

Untuk mutu beton yang tidak terdapat concrete mix design-nya seperti mutu 15 MPa dan 30 MPa, digunakan material yang sudah tersedia yang memiliki mutu hampir setara. Berikut adalah contoh pengisian material untuk mutu 30 MPa.



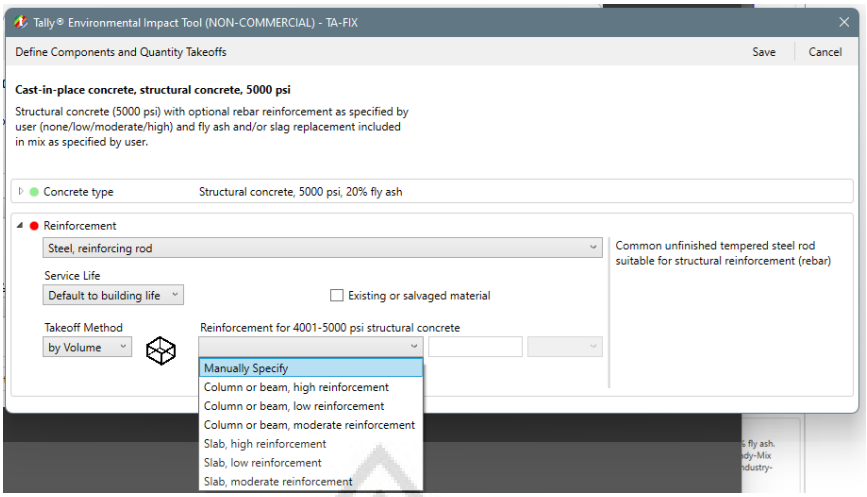
Gambar 16. Menu Beton

Mutu yang digunakan adalah beton dengan kekuatan 5000 psi yang menggunakan fly ash 20%.

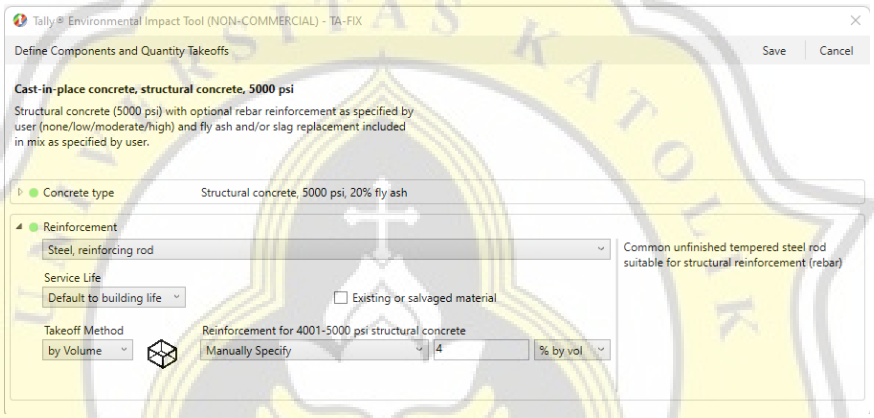


Gambar 17. Pengisian *Concrete Type*

Kemudian untuk tipe tulangannya dipilih manually specify agar seragam dengan mutu beton yang memiliki concrete mix design.

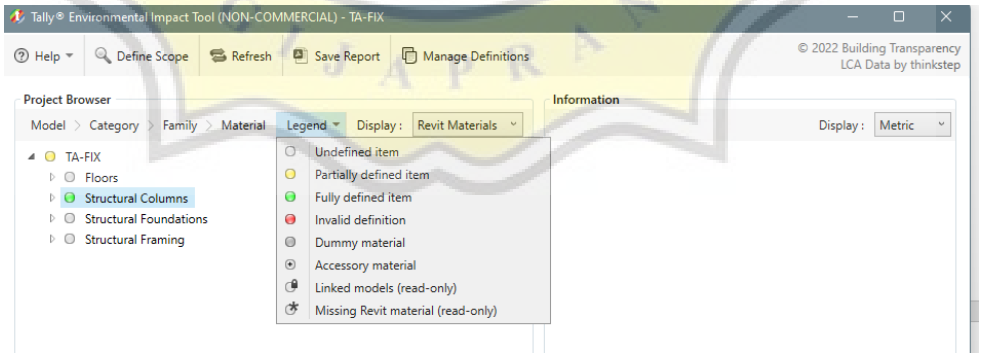


Gambar 18. Jenis Tulangan



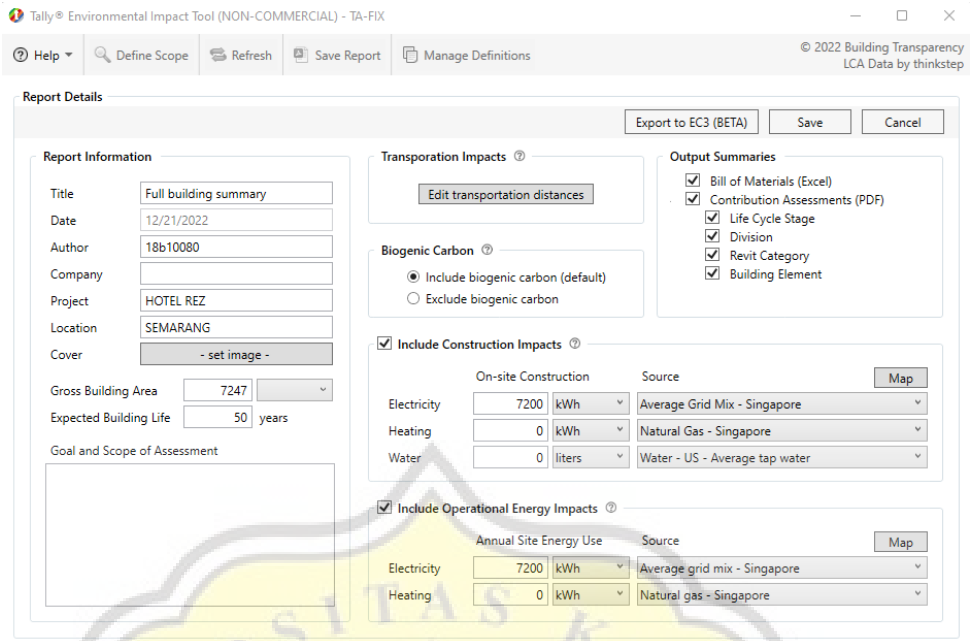
Gambar 19. Pengisian Tulangan

Setelah komponen terdefinisikan, maka indikator akan berubah menjadi hijau. Warna indikator dan penjelasannya diperlihatkan pada Gambar 20.



Gambar 20. Penjelasan Indikator

Setelah semua komponen material terdefinisi, laporan dapat disimpan dengan cara menekan menu *Save Report.* Maka akan muncul window seperti pada Gambar 21.



Gambar 21. *Report Details*

Gross building area diisi sesuai dengan luas struktur bangunan yaitu 7247 m^2 dengan masa layan bangunan diasumsikan 50 tahun. Untuk Listrik selama masa konstruksi dan operational diisi 7200 kWh sedangkan untuk *heating* dan *water* tidak diisi karena proyek yang digunakan tidak menggunakan *heating* dan jumlah air yang digunakan selama masa konstruksi tidak diketahui. Setelah semua kolom telah diisi dapat dipilih *save*.

LAMPIRAN C

Tugas AKhir

Full building summary

12/26/2022

tally®

Table of Contents

Report Summary

Created with Tally
Non-commercial Version 2022.04.08.01

Goal and Scope of Assessment
Trial

Author 18b10080
Company Unika
Date 12/26/2022

Project Tugas AKhir
Location SEMARANG
Gross Area 7247 m^2
Building Life 50 years

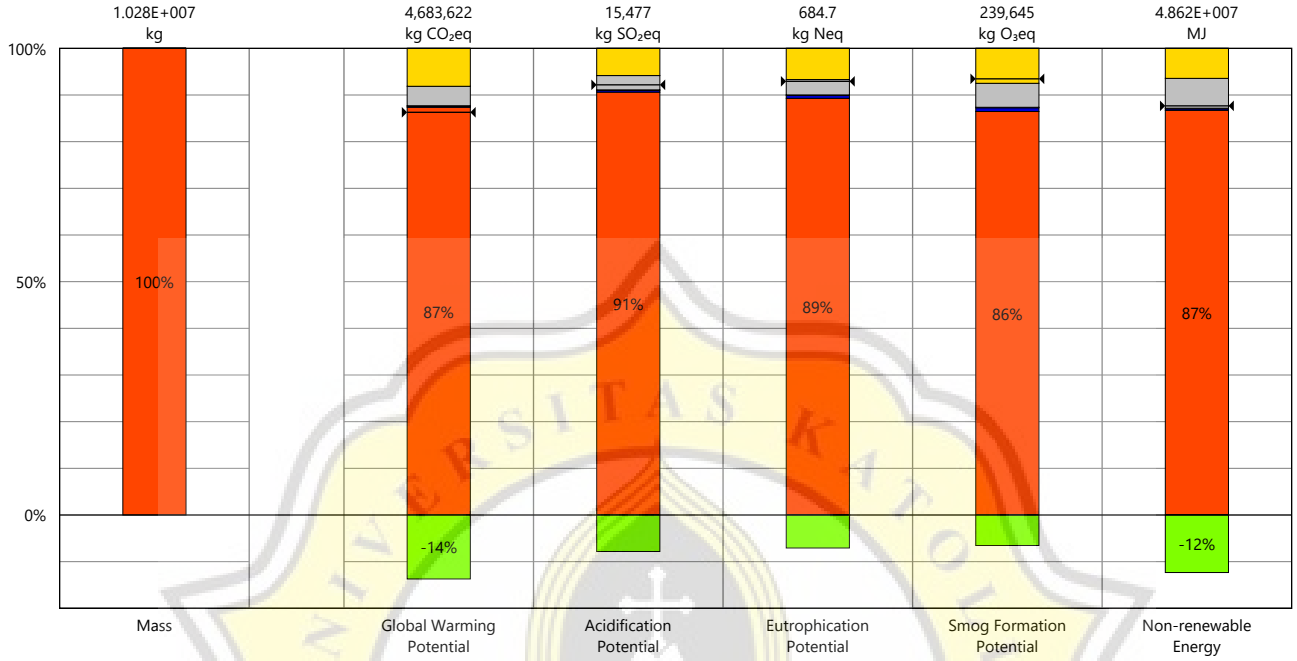
Boundaries Cradle to grave, inclusive of biogenic carbon; see appendix for a full list of materials and processes

On-site Construction [A5] 7200 kWh electricity use
0 kWh heating energy use
0 liters water use

Operational Energy [B6] 7200 kWh annual electricity use
0 kWh annual heating energy use

Environmental Impact Totals	Product Stage [A1-A3]	Construction Stage [A4-A5]	Use Stage [B2-B6]	End of Life Stage [C2-C4]	Module D [D]
Global Warming (kg CO_2eq)	4,092,098	15,092	195,480	380,952	-642,035
Acidification (kg SO_2eq)	14,024	74.61	475.2	903.2	-1,211
Eutrophication (kg Neq)	611.3	5.001	22.57	45.80	-48.4
Smog Formation (kg O_3eq)	207,202	2,170	12,312	17,961	-15,667
Ozone Depletion (kg CFC-11eq)	-0.01062	3.805E-010	5.256E-011	3.593E-008	0.0046
Primary Energy (MJ)	4.414E+007	224,381	3,132,000	3,346,307	-5,604,961
Non-renewable Energy (MJ)	4.216E+007	220,194	3,110,400	3,128,732	-5,994,298
Renewable Energy (MJ)	2,016,876	4,233	22,536	221,072	387,742
Environmental Impacts / Area					
Global Warming (kg CO_2eq/m^2)	564.7	2.083	26.97	52.57	-88.6
Acidification (kg SO_2eq/m^2)	1.935	0.0103	0.06557	0.1246	-0.1671
Eutrophication (kg Neq/m^2)	0.08435	6.900E-004	0.003115	0.00632	-0.006683
Smog Formation (kg O_3eq/m^2)	28.59	0.2994	1.699	2.478	-2.16
Ozone Depletion (kg CFC-11eq/m^2)	-1.465E-006	5.250E-014	7.253E-015	4.959E-012	6.347E-007
Primary Energy (MJ/m^2)	6,091	30.96	432.2	461.8	-773
Non-renewable Energy (MJ/m^2)	5,818	30.38	429.2	431.7	-827
Renewable Energy (MJ/m^2)	278.3	0.5841	3.110	30.51	53.50

Results per Life Cycle Stage

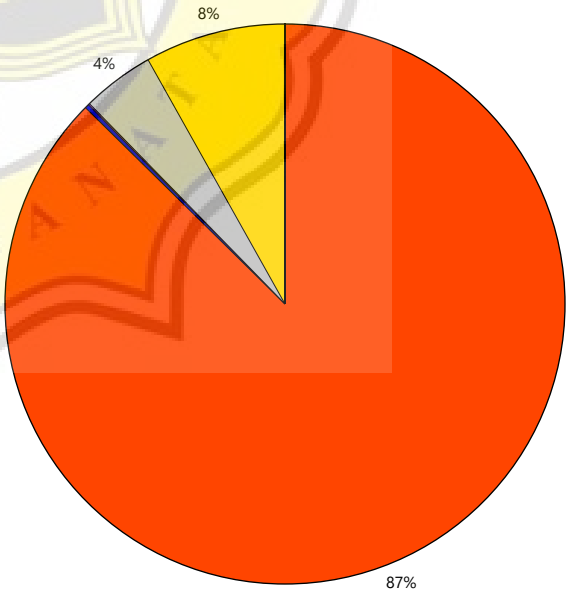


Legend

Net value (impacts + credits)

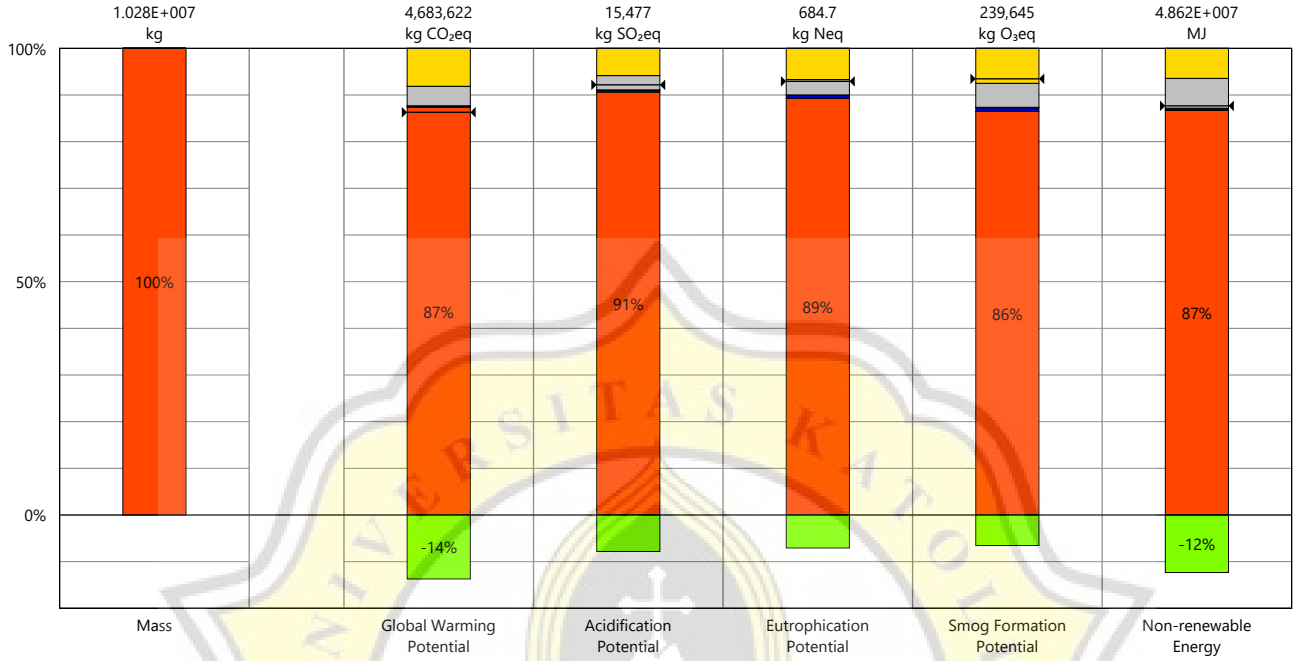
Life Cycle Stages

- Product [A1-A3]
- Transportation [A4]
- On-site Construction [A5]
- Maintenance and Replacement [B2-B5]
- Operational Energy [B6]
- End of Life [C2-C4]
- Module D [D]



Global Warming Potential

Results per Life Cycle Stage, itemized by Division



Legend

Net value (impacts + credits)

Product [A1-A3]
- 03 - Concrete

Transportation [A4]
- 03 - Concrete

On-site Construction [A5]
- Electricity
- Heating
- Water

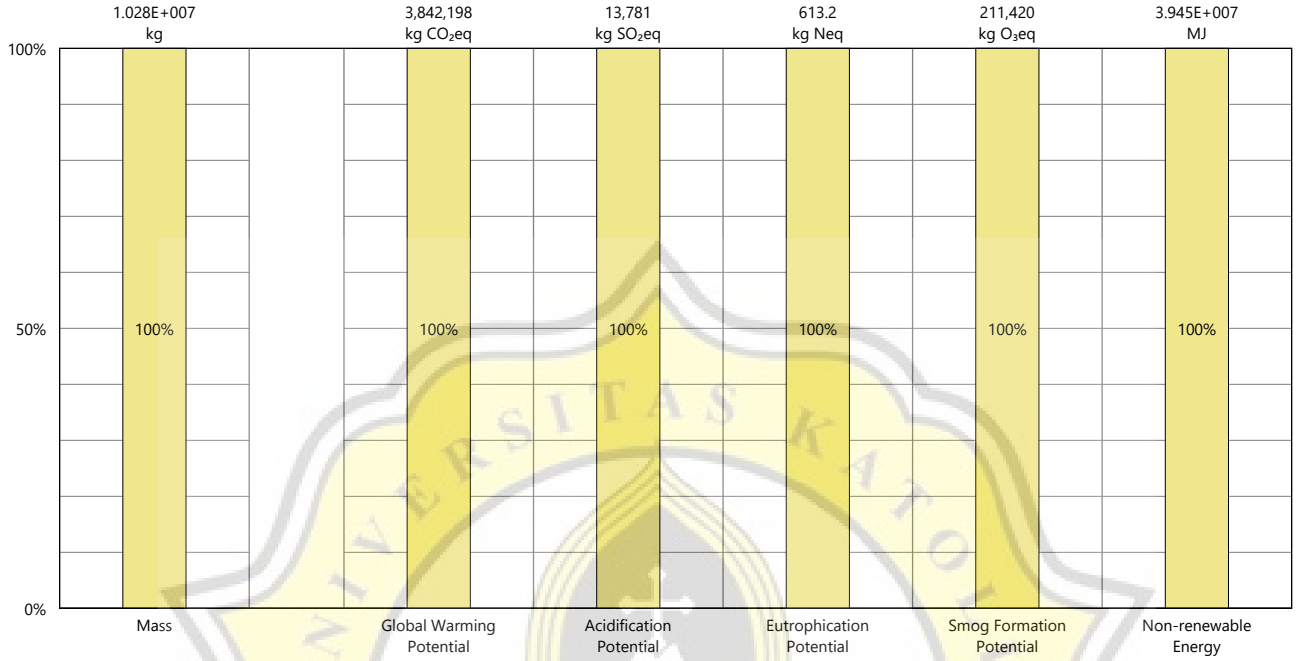
Maintenance and Replacement [B2-B5]
- 03 - Concrete

Operational Energy [B6]
- Electricity
- Heating

End of Life [C2-C4]
- 03 - Concrete

Module D [D]
- 03 - Concrete

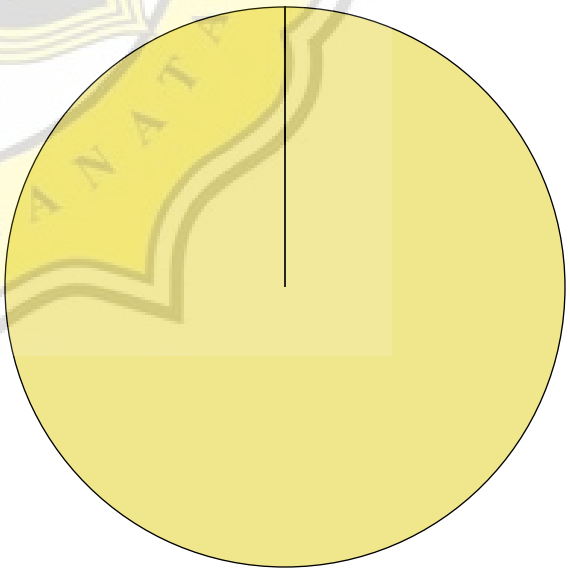
Results per Division



Legend

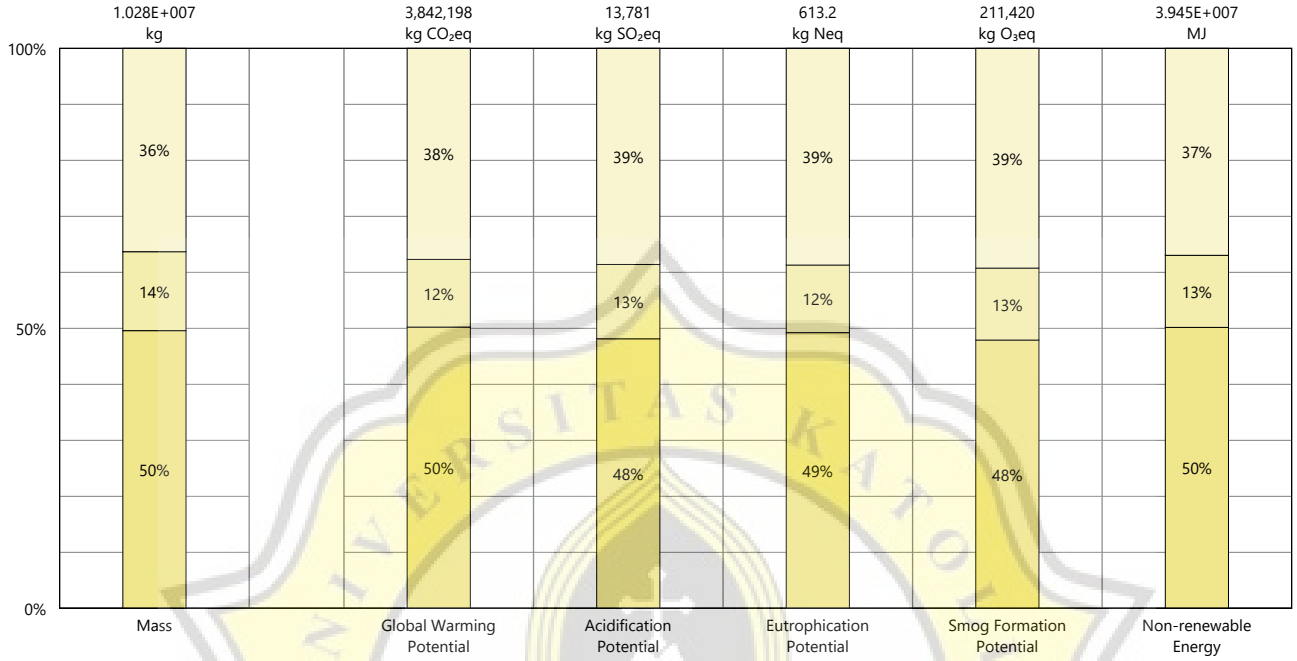
Divisions

03 - Concrete



Global Warming Potential

Results per Division, itemized by Tally Entry

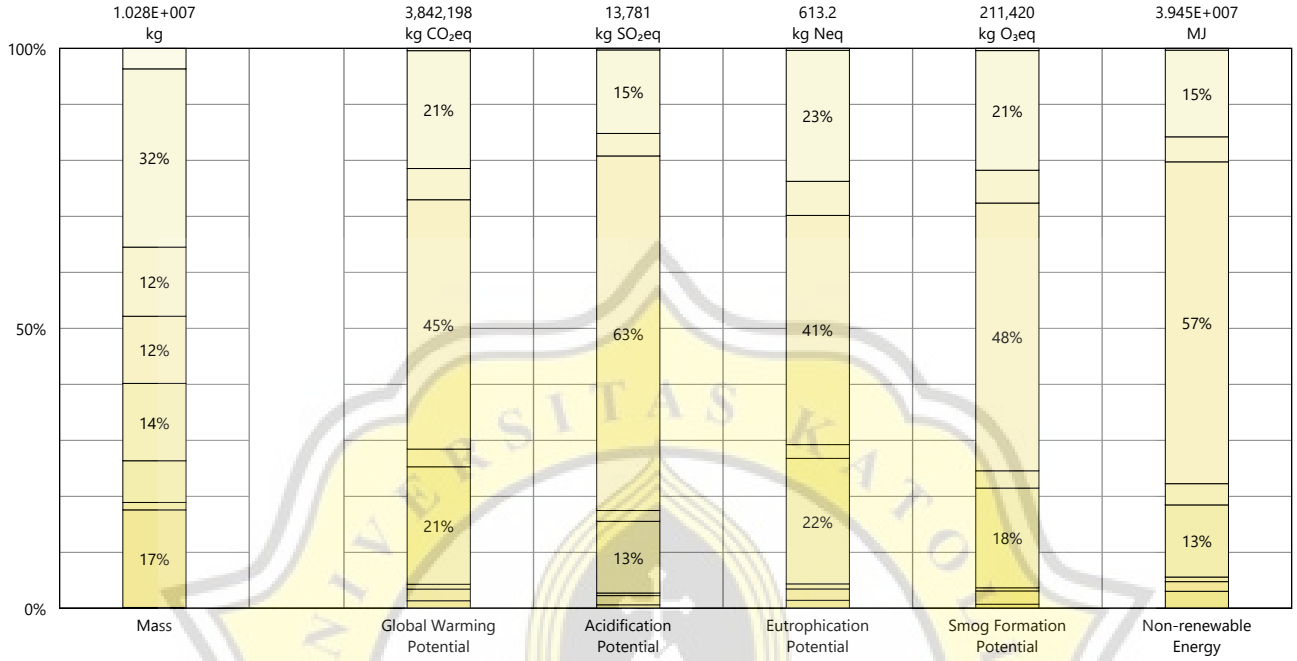


Legend

03 - Concrete

- Cast-in-place concrete, custom mix
- Cast-in-place concrete, structural concrete, 2500 psi
- Cast-in-place concrete, structural concrete, 5000 psi

Results per Division, itemized by Material

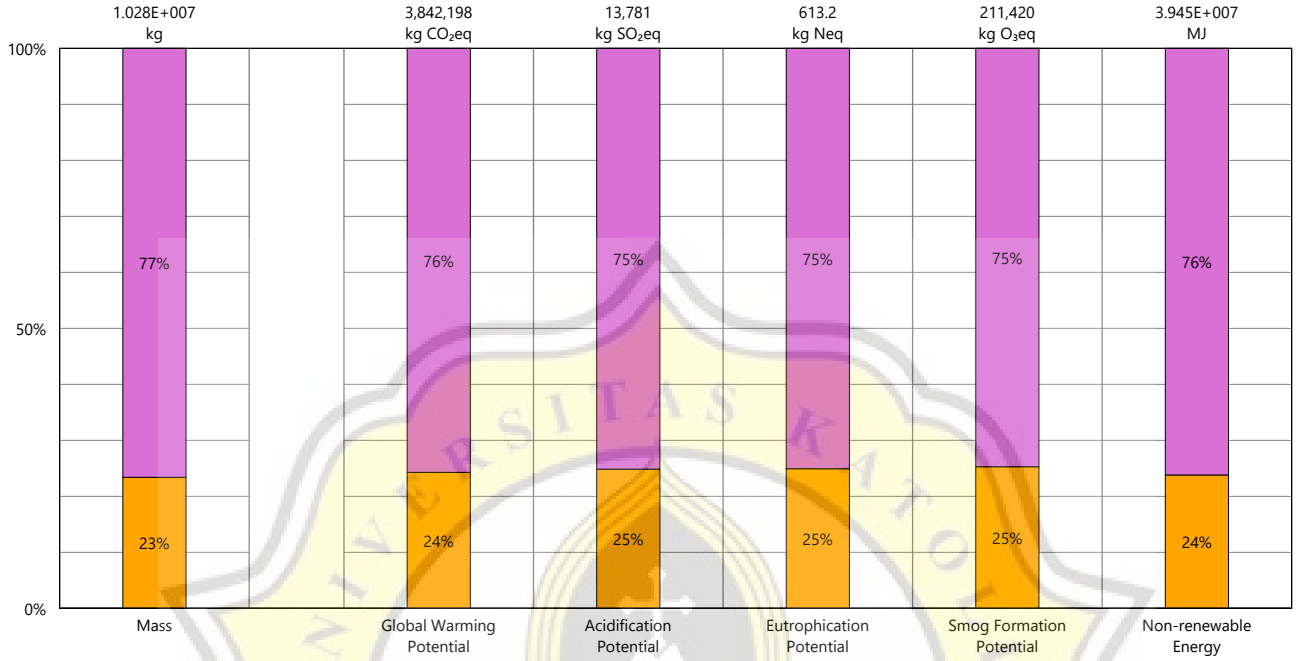


Legend

03 - Concrete

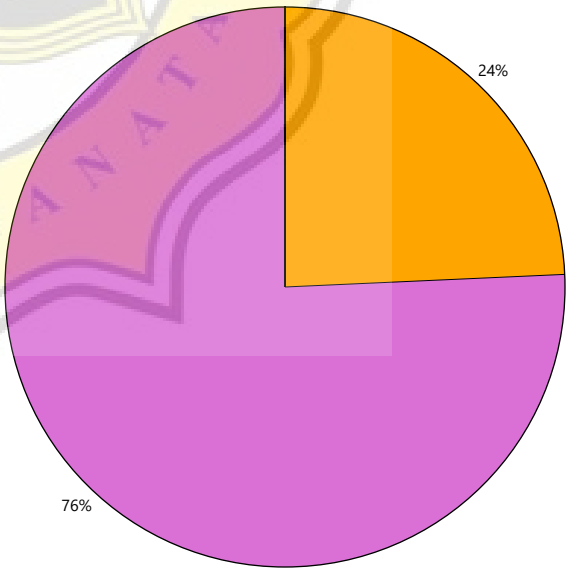
- Admixture
- Coarse aggregate
- Fly ash
- Portland cement, PCA - EPD
- Sand
- Steel, reinforcing rod
- Structural concrete, 2500 psi, 20% fly ash
- Structural concrete, 5000 psi, 20% fly ash
- Water

Results per Revit Category



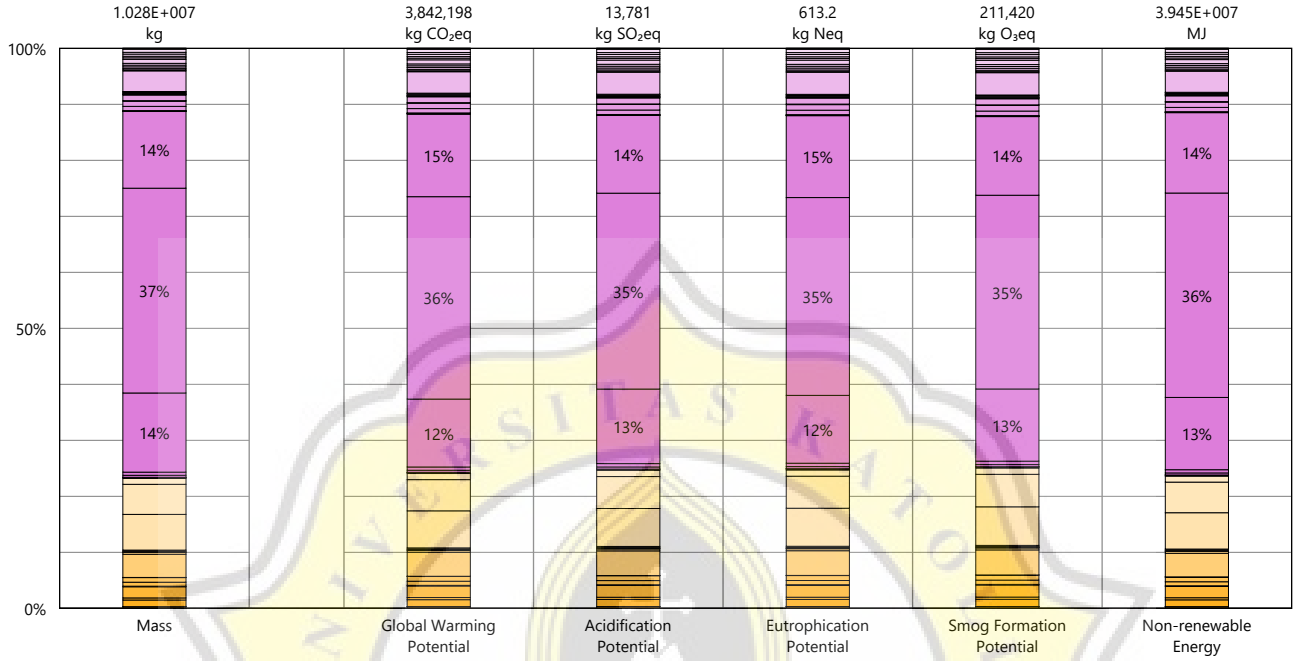
Legend

Revit Categories
- Floors
- Structure



Global Warming Potential

Results per Revit Category, itemized by Family



Legend

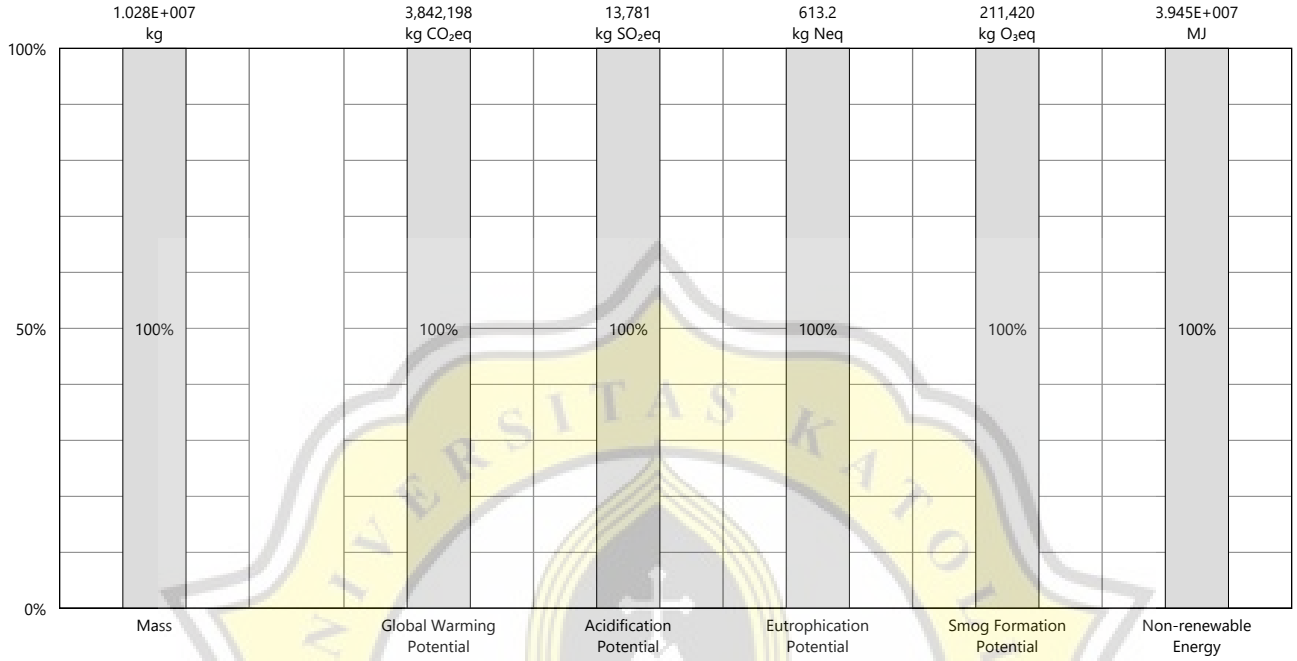
Floors

- ADD.S1
- ADD.TG-5
- ADD.TG-5'
- BS1
- BS2
- BS3
- BS4
- BS5
- BS6
- CHAM.STP
- CHAM.STP-1
- CS1
- FH.BS3
- FH.BS4
- GTR.A
- GTR.B
- S1
- S2
- S3
- SLUDGE
- SS

Structure

- ADD.B14
- ADD.B17
- ADD.P38
- Beam Concrete Rectangular Crank
- Beam Concrete-Rectangular
- Bore Pile Dia.600
- Column Concrete-Rectangular
- Corbel Ramp
- Corbel Ramp-1
- F1
- P1
- P1'
- P12
- P13
- P1A'
- P1A"
- P1A.A
- P1B
- P1B'
- P2
- P2'.A
- P2-1
- P38
- P4
- P4-1
- P5
- P5-1
- P5-2
- P6
- P6-1
- P6-2
- P7
- P7-1
- P8
- PON.BLOWER
- PON.GST
- PON.PUMP
- PON.PUMP 2
- PON.TRAVO

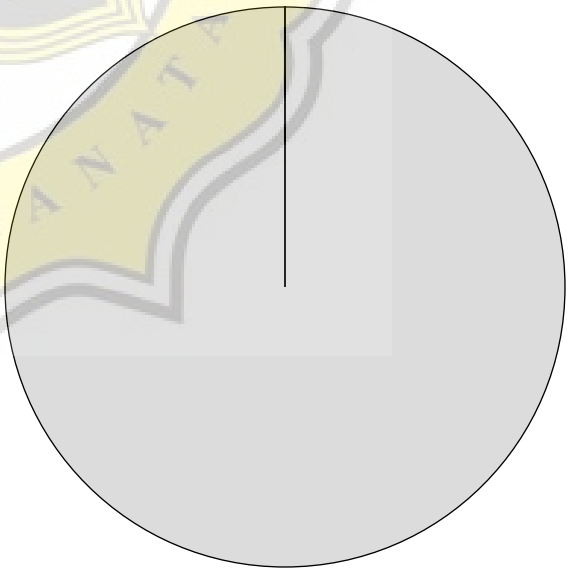
Results per Building Element



Legend

Building Elements

Undefined



Global Warming Potential

Calculation Methodology

LIFE CYCLE ASSESSMENT METHODS

The following provides a description of terms and methods associated with the use of Tally to conduct life cycle assessment for construction works and construction products. Tally methodology is consistent with LCA standards ISO 14040-14044, ISO 21930:2017, ISO 21931:2010, EN 15804:2012, and EN 15978:2011. For more information about LCA, please refer to these standards or visit www.choosetally.com.

Studied objects

The life cycle assessment (LCA) results reported represent an analysis of a single building, multiple buildings, or a comparative analysis of two or more building design options. The assessment may represent the complete architectural, structural, and finish systems of the building(s) or a subset of those systems. This may be used to compare the relative environmental impacts associated with building components or for comparative study with one or more reference buildings. Design options may represent a full or partial building across various stages of the design process, or they may represent multiple schemes of a full or partial building that are being compared to one another across a range of evaluation criteria.

Functional unit and reference unit

A functional unit is the quantified performance of a product, building, or system that defines the object of the study. The functional unit of a single building should include the building type (e.g. office, factory), relevant technical and functional requirements (e.g. regulatory requirements, energy performance), pattern of use (e.g. occupancy, usable floor area), and the required service life. For a design option comparison of a partial building, the functional unit is the complete set of building systems or products that perform a given function. It is the responsibility of the modeler to assure that reference buildings or design options are functionally equivalent in terms of scope and relevant performance. The expected life of the building has a default value of 60 years and can be modified by the modeler.

The reference unit is the full collection of processes and materials required to produce a building or portion thereof and is quantified according to the given goal and scope of the assessment over the full life of the building. If construction impacts are included in the assessment, the reference unit also includes the energy, water, and fuel consumed on the building site during construction. If operational energy is included in the assessment, the reference unit includes the electrical and thermal energy consumed on site over the life of the building.

Data source

Tally utilizes a custom designed LCA database that combines material attributes, assembly details, and architectural specifications with environmental impact data resulting from the collaboration between KieranTimberlake and thinkstep. LCA modeling was conducted in GaBi 8.5 using GaBi 2018 databases and in accordance with GaBi databases and modeling principles.

The data used are intended to represent the US and the year 2017. Where representative data were unavailable, proxy data were used. The datasets used, their geographic region, and year of reference are listed for each entry. An effort was made to choose proxy datasets that are technologically consistent with the relevant entry.

Data quality and uncertainty

Uncertainty in results can stem from both the data used and their application. Data quality is judged by: its measured, calculated, or estimated precision; its completeness, such as unreported emissions; its consistency, or degree of uniformity of the methodology applied on a study serving as a data source; and geographical, temporal, and technological representativeness. The GaBi LCI databases have been used in LCA models worldwide in both industrial and scientific applications. These LCI databases have additionally been used both as internal and critically reviewed and published studies. Uncertainty introduced by the use of proxy data is reduced by using technologically, geographically, and/or temporally similar data. It is the responsibility of the modeler to appropriately apply the predefined material entries to the building under study.

System boundaries and delimitations

The analysis accounts for the full cradle to grave life cycle of the design options studied across all life cycle stages, including material manufacturing, maintenance and replacement, and eventual end of life. Optionally, the construction impacts and operational energy of the building can be included within the scope. Product stage impacts are excluded for materials and components indicated as existing or salvaged by the modeler. The modeler defines whether the boundary includes or excludes the flow of biogenic carbon, which is the carbon absorbed and generated by biological sources (e.g. trees, algae) rather than from fossil resources.

Architectural materials and assemblies include all materials required for the product's manufacturing and use including hardware, sealants, adhesives, coatings, and finishing. The materials are included up to a 1% cut-off factor by mass except for known materials that have high environmental impacts at low levels. In these cases, a 1% cut-off was implemented by impact.

Calculation Methodology

LIFE CYCLE STAGES

The following describes the scope and system boudaries used to define each stage of the life cycle of a building or building product, from raw material acquisition to final disposal. For products listed in Tally as Environmental Product Declarations (EPD), the full life cycle impacts are included, even if the published EPD only includes the Product stage [A1-A3].

Product [EN 15978 A1 - A3]

This encompasses the full manufacturing stage, including raw material extraction and processing, intermediate transportation, and final manufacturing and assembly. The product stage scope is listed for each entry, detailing any specific inclusions or exclusions that fall outside of the cradle to gate scope. Infrastructure (buildings and machinery) required for the manufacturing and assembly of building materials are not included and are considered outside the scope of assessment.

Transportation [EN 15978 A4]

This counts transportation from the manufacturer to the building site during the construction stage and can be modified by the modeler.

Construction Installation [EN 15978 A5] (Optional)

This includes the anticipated or measured energy and water consumed on-site during the construction installation process, as specified by the modeler.

Maintenance and Replacement [EN 15978 B2-B5]

This encompasses the replacement of materials in accordance with their expected service life. This includes the end of life treatment of the existing products as well as the cradle to gate manufacturing and transportation to site of the replacement products. The service life is specified separately for each product. Refurbishment of materials marked as existing or salvaged by the modeler is also included.

Operational Energy [EN 15978 B6] (Optional)

This is based on the anticipated or measured energy and natural gas consumed at the building site over the lifetime of the building, as indicated by the modeler.

End of Life [EN 15978 C2-C4]

This includes the relevant material collection rates for recycling, processing requirements for recycled materials, incineration rates, and landfilling rates. The impacts associated with landfilling are based on average material properties, such as plastic waste, biodegradable waste, or inert material. Stage C2 encompasses the transport from the construction site to end-of-life treatment based on national averages. Stages C3-C4 account for waste processing and disposal, i.e., impacts associated with landfilling or incineration.

Module D [EN 15978 D]

This accounts for reuse potentials that fall beyond the system boundary, such as energy recovery and recycling of materials. Along with processing requirements, the recycling of materials is modeled using an avoided burden approach, where the burden of primary material production is allocated to the subsequent life cycle based on the quantity of recovered secondary material. Incineration of materials includes credit for average US energy recovery rates.

PRODUCT	CONSTRUCTION	USE	END-OF-LIFE	MODULE D
A1. Extraction	**A4. Transport (to site)**	B1. Use	C1. Demolition	**D. Benefits and loads beyond the system boundary from:**
A2. Transport (to factory)	***A5. Construction Installation***	**B2. Maintenance**	**C2. Transport (to disposal)**	**1. Reuse**
A3. Manufacturing		**B3. Repair**	**C3. Waste processing**	**2. Recycling**
		B4. Replacement	**C4. Disposal**	**3. Energy recovery**
		B5. Refurbishment		
		B6. Operational energy		
		B7. Operational water		

Life-Cycle Stages as defined by EN 15978. Processes included in Tally modeling scope are shown in bold. Italics indicate optional processes.

Calculation Methodology

ENVIRONMENTAL IMPACT CATEGORIES

A characterization scheme translates all emissions and fuel use associated with the reference flow into quantities of categorized environmental impact. As the degree that the emissions will result in environmental harm depends on regional ecosystem conditions and the location in which they occur, the results are reported as impact potential. Potential impacts are reported in kilograms of equivalent relative contribution (eq) of an emission commonly associated with that form of environmental impact (e.g. kg CO_2eq).

The following list provides a description of environmental impact categories reported according to the TRACI 2.1 characterization scheme, the environmental impact model developed by the US EPA to quantify environmental impact risk associated with emissions to the environment in the United States. TRACI is the standard environmental impact reporting format for LCA in North America. Impacts associated with land use change and fresh water depletion are not included in TRACI 2.1. For more information on TRACI 2.1, reference Bare 2010, EPA 2012, and Guinée 2001. For further description of measurement of environmental impacts in LCA, see Simonen 2014.

Acidification Potential (AP) kg SO_2eq

A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H^+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.

Eutrophication Potential (EP) kg Neq

A measure of the impacts of excessively high levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems, increased biomass production may lead to depressed oxygen levels caused by the additional consumption of oxygen in biomass decomposition.

Global Warming Potential (GWP) kg CO_2eq

A measure of greenhouse gas emissions, such as carbon dioxide and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may, in turn, have adverse impacts on ecosystem health, human health, and material welfare.

Ozone Depletion Potential (ODP) kg CFC-11eq

A measure of air emissions that contribute to the depletion of the stratospheric ozone layer. Depletion of the ozone leads to higher levels of UVB ultraviolet rays reaching the earth's surface with detrimental effects on humans and plants. As these impacts tend to be very small, ODP impacts can be difficult to calculate and are prone to a larger margin of error than the other impact categories.

Smog Formation Potential (SFP) kg O_3eq

A measure of ground level ozone, caused by various chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in sunlight. Human health effects can result in a variety of respiratory issues, including increasing symptoms of bronchitis, asthma, and emphysema. Permanent lung damage may result from prolonged exposure to ozone. Ecological impacts include damage to various ecosystems and crop damage.

Primary Energy Demand (PED) MJ (lower heating value)

A measure of the total amount of primary energy extracted from the earth. PED tracks energy resource use, not the environmental impacts associated with the resource use. PED is expressed in energy demand from non-renewable resources and from renewable resources. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Non-Renewable Energy Demand MJ (lower heating value)

A measure of the energy extracted from non-renewable resources (e.g. petroleum, natural gas, etc.) contributing to the PED. Non-renewable resources are those that cannot be regenerated within a human time scale. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

Renewable Energy Demand MJ (lower heating value)

A measure of the energy extracted from renewable resources (e.g. hydropower, wind energy, solar power, etc.) contributing to the PED. Efficiencies in energy conversion (e.g. power, heat, steam, etc.) are taken into account when calculating this result.

LCI Data

END-OF-LIFE [C2-C4]

A Life Cycle Inventory(LCI) is a compilation and quantification of inputs and outputs for the reference unit.The following LCI provides a summary of all energy, construction, transportation, and material inputs present in the study. Materials are listed in alphabetical order along with a list of all Revit families and Tally entries in which they occur, along with any notes and system boundaries accompanying their database entries. Each entry lists the detailed scope for the LCI data sources used from the GaBi LCI database and identifies the LCI data source.

For LCI data sourced from an Environmental Product Declaration (EPD), the product manufacturer, EPD identification number, and Program Operator are listed. Where the LCI source does not provide data for all life cycle stages, default North American average values are used. This is of particular importance for European EPD sources, as EPD data are generally only provided for the product stage, and North American average values are used for the remaining life cycle stages.

Where specific quantities are associated with a data entry, such as user inputs, energy values, or material mass, the quantity is listed on the same line as the title of the entry.

TRANSPORTATION [A4]

Default transportation values are based on the three-digit material commodity code in the 2012 Commodity Flow Survey by the US Department of Transportation Bureau of Transportation Statistics and the US Department of Commerce where more specific industry-level transportation is not available.

Transportation by Barge
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by barge.

LCI Source:
GLO: Average ship, 1500t payload capacity/ canal ts (2017)
US: Diesel mix at filling station ts (2014)

Transportation by Container Ship
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by container ship.

LCI Source:
GLO: Container ship, 27500 dwt payload capacity, ocean going ts (2017)
US: Heavy fuel oil at refinery (0.3wt.% S) ts (2014)

Transportation by Rail
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by cargo rail.

LCI Source:
GLO: Rail transport cargo - Diesel, average train, gross tonne weight 1000t / 726t payload capacity ts (2017)
US: Diesel mix at filling station ts (2014)

Transportation by Truck
Scope:
The data set represents the transportation of 1 kg of material from the manufacturer location to the building site by diesel truck.

LCI Source:
US: Truck - Trailer, basic enclosed / 45,000 lb payload - 8b ts (2017)
US: Diesel mix at filling station ts (2014)

LCI Data (continued)

CONSTRUCTION INSTALLATION [A5]

Each associated dataset includes relevant upstream impacts associated with extraction of energy resources (such as coal or crude oil), including refining, combustion, transmission, losses, and other associated factors.

On-site Construction Electrical Energy **7200 kWh**

Description:
Average Grid Mix - Singaporian electricity grid mix

Scope:
The data set represents the average country or region specific electricity supply for final consumers, including electricity own consumption, transmission/distribution losses and electricity imports from neighboring countries. The national energy carrier mixes used for electricity production, the power plant efficiency data, shares on direct to combined heat and power generation (CHP), as well as transmission/distribution losses and own consumption values are taken from official statistics (International Energy Agency, and US-EPA eGRID for USA regions) for the corresponding reference year.

LCI Source:
SG: Electricity grid mix ts (2014)

On-site Construction Heating Energy **0 kWh**

Description:
Natural Gas - Singaporean natural gas

Scope:
The data set represents region-specific natural gas use for temporary heating of a construction site. Entry includes upstream production of natural gas, transport from refinery to filling station, and on-site combustion.

LCI Source:
SI: Thermal energy from natural gas ts (2014)

On-site Construction Water **0 liters**

Description:
Water - US average groundwater

Scope:
The data set represents the average country specific water supply for site construction, from groundwater. Entry includes the extraction and purification of ground water, delivery of ground water to tap, and treatment of incoming municipal waste water treatment.

LCI Source:
US: Tap water from groundwater
ts (2017); US: Municipal Waste water treatment (US average, avoided burden) ts (2017)

OPERATIONAL ENERGY [B6]

Each associated dataset includes relevant upstream impacts associated with extraction of energy resources (such as coal or crude oil), including refining, combustion, transmission, losses, and other associated factors.

Operational Electrical Energy **7200 kWh**

Description:
Average grid mix - Singaporian electricity grid mix

Scope:
The data set represents the average country or region specific electricity supply for final consumers, including electricity own consumption, transmission/distribution losses and electricity imports from neighboring countries. The national energy carrier mixes used for electricity production, the power plant efficiency data, shares on direct to combined heat and power generation (CHP), as well as transmission/distribution losses and own consumption values are taken from official statistics (International Energy Agency, and US-EPA eGRID for USA regions) for the corresponding reference year.

LCI Source:
SG: Electricity grid mix ts (2014)

Operational Heating Energy **0 kWh**

Description:
Natural gas - Singaporean natural gas

Scope:
The data set represents region-specific natural gas use for heating during building use and operations. Entry includes upstream production of natural gas, transport from refinery to filling station, and on-site combustion.

LCI Source:
SI: Thermal energy from natural gas ts (2014)

LCI Data (continued)

END-OF-LIFE [C2-C4]

Specific end-of-life scenarios are detailed for each entry based on the US construction and demolition waste treatment methods and rates in the 2016 WARM Model by the US Environmental Protection Agency except where otherwise specified. Heterogeneous assemblies are modeled using the appropriate methodologies for the component materials.

End-of-Life Landfill

Scope:

Materials for which no recycling or incineration rates are known, no recycling occurs within the US at a commercial scale, or which are unable to be recycled are landfilled. This includes glass, drywall, insulation, and plastics. The solids contents of coatings, sealants, and paints are assumed to go to landfill, while the solvents or water evaporate during installation. Where the landfill contains biodegradable material, the energy recovered from landfill gas utilization is reflected as a credit in Module D.

LCI Source:

US: Glass/inert on landfill ts (2017)
US: Biodegradable waste on landfill, post-consumer ts (2017)
US: Plastic waste on landfill, post-consumer ts (2017)

Concrete End-of-Life

Scope:

Concrete (or other masonry products) are recycled into aggregate or general fill material or they are landfilled. It is assumed that 55% of the concrete is recycled. Module D accounts for both the credit associated with off-setting the production aggregate and the burden of the grinding energy required for processing.

LCI Source:

US: Diesel mix at refinery ts (2014)
GLO: Fork lifter (diesel consumption) ts (2016)
EU - 28 Gravel 2/32 ts (2017)
US: Glass/inert on landfill ts (2017)

Metals End-of-Life

Scope:

Metal products are modeled using the avoided burden approach. The recycling rate at end of life is used to determine how much secondary metal can be recovered after having subtracted any scrap input into manufacturing (net scrap). Net scrap results in an environmental credit in Module D for the corresponding share of the primary burden that can be allocated to the subsequent product system using secondary material as an input. If the value in Module D reflects an environmental burden, then the original product (A1-A3) contains more secondary material than is recovered.

LCI Source:

Aluminum - RNA: Primary Aluminum Ingot AA/ts (2010)
Aluminum - RNA: Secondary Aluminum Ingot AA/ts (2010)
Brass - GLO: Zinc mix ts (2012)
Brass - GLO: Copper (99.99% cathode) ICA (2013)
Brass - EU-28: Brass (CuZn20) ts (2017)
Copper - DE: Recycling potential copper sheet ts (2016)
Steel - GLO: Value of scrap worldsteel (2014)
Zinc - GLO: Special high grade zinc IZA (2012)

Wood End-of-Life

Scope:

End of Life waste treatment methods and rates for wood are based on the 2014 Municipal Solid Waste and Construction Demolition Wood Waste Generation and Recovery in the United States report by Dovetail Partners, Inc. It is assumed that 63.5% of wood is sent to landfill, 22% to incineration, and 14.5% to recovery.

LCI Source:

US: Untreated wood in waste incineration plant ts (2017)
US: Wood product (OSB, particle board) waste in waste incineration plant ts (2017)
US: Wood products (OSB, particle board) on landfill, post-consumer ts (2017)
US: Untreated wood on landfill, post-consumer ts (2017)
RNA: Softwood lumber CORRIM (2011)

LCI Data

MODEL ELEMENTS

Revit Categories
- Floors
- Structure

TA-FIX
- Worksets
  - Workset1
- Phases
  - Basemen
  - Existing
  - Final
  - Galian
  - Lantai GF
  - New Construction
  - Pemancangan
  - Podium
  - Pondasi
  - Tower Tipikal
  - Tower Toping Off

BAJA BALKON (Read-only)
- Worksets
  - N/A
- Phases
  - N/A

PRODUCT [A1-A3]

Materials and components are listed in alphabetical order along with a list of all Revit families and Tally entries in which they occur. The masses given here refer to the quantity of each material used over the building's life-cycle, which includes both Product [A1-A3] and Use [B2-B5] stages.

Additional provided data describing scope boundaries for each life cycle stage may be useful for interpretation of the impacts associated with the specific material or component. Each material or component is listed with its service life, or period of time after installation it is expected to meet the service requirements prior to replacement or repair. This value is indicated in parentheses next to the mass of the material associated with the listed Revit family. Values for transportation distance or service life shown with an asterisk (*) indicate user-defined changes to default values. Values for service life shown with a dagger (†) indicate materials identified by the modeler as existing or salvaged.

Admixture **15,830.6 kg**

Used in the following Revit families:

Bore Pile Dia.600	11,694.3 kg (50 yrs)
Column Concrete-Rectangular	4,128.9 kg (50 yrs)
Corbel Ramp	2.9 kg (50 yrs)
Corbel Ramp-1	4.5 kg (50 yrs)

Used in the following Tally entries:
- Cast-in-place concrete, custom mix

Description:
- Concrete mix ingredient: Average admixture

Life Cycle Inventory:
- 50% Diethanolamine
- 50% Alcohol ethoxy sulfate

Product Scope:
- Cradle to gate, excludes mixing and pouring impacts

Transportation Distance:
- By rail: 0 km*
- By truck: 19 km*

End-of-Life Scope:
- 55% Recycled into coarse aggregate
- 45% Landfilled (inert material)

Module D Scope:
- Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
- US: Diethanolamine (DEA) ts (2017)
- US: Tensides (alcohol ethoxy sulfate (AES)) ts (2017)

Coarse aggregate **1,792,142.6 kg**

Used in the following Revit families:

Bore Pile Dia.600	1,329,416.8 kg (50 yrs)
Column Concrete-Rectangular	461,895.0 kg (50 yrs)
Corbel Ramp	324.5 kg (50 yrs)
Corbel Ramp-1	506.3 kg (50 yrs)

Used in the following Tally entries:
- Cast-in-place concrete, custom mix

Description:
- Concrete mix ingredient: Gravel

Life Cycle Inventory:
- Gravel

Product Scope:
- Cradle to gate, excludes mixing and pouring impacts

Transportation Distance:
- By barge: 0 km*
- By container ship: 12 km
- By rail: 0 km*

LCI Data (continued)

By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
EU-28: Gravel 2/32 ts (2017)

Fly ash **135,739.5 kg**

Used in the following Revit families:

Bore Pile Dia.600	93,883.9 kg (50 yrs)
Column Concrete-Rectangular	41,780.4 kg (50 yrs)
Corbel Ramp	29.4 kg (50 yrs)
Corbel Ramp-1	45.8 kg (50 yrs)

Used in the following Tally entries:
Cast-in-place concrete, custom mix

Description:
Concrete mix ingredient: Fly ash
50 pcf

Life Cycle Inventory:
Fly ash

Product Scope:
Cradle to gate, excludes mixing and pouring impacts

Transportation Distance:
By container ship: 0 km*
By rail: 0 km*
By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
DE: Fly ash (EN15804 A1-A3) ts (2017)

Portland cement, PCA - EPD **766,049.7 kg**

Used in the following Revit families:

Bore Pile Dia.600	529,688.7 kg (50 yrs)
Column Concrete-Rectangular	235,936.6 kg (50 yrs)
Corbel Ramp	165.8 kg (50 yrs)
Corbel Ramp-1	258.6 kg (50 yrs)

Used in the following Tally entries:
Cast-in-place concrete, custom mix

Description:
Concrete mix ingredient: portland cement. Data is based on Industry-wide EPD from the Portland Cement Association.

Life Cycle Inventory:
For information and quantities, see EPD

Product Scope:
Cradle to gate

Transportation Distance:
By barge: 0 km*
By container ship: 0 km*
By rail: 0 km*
By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
US: Portland cement PCA/ts (2014)

EPD Source:
EPD 035

EPD Designation Holder:
Portland Cement Association

EPD Program Operator:
ASTM International

EPD Expiration:
5/31/2021

Sand **1,420,047.3 kg**

Used in the following Revit families:

Bore Pile Dia.600	1,079,638.2 kg (50 yrs)
Column Concrete-Rectangular	339,797.8 kg (50 yrs)
Corbel Ramp	238.8 kg (50 yrs)
Corbel Ramp-1	372.4 kg (50 yrs)

Used in the following Tally entries:
Cast-in-place concrete, custom mix

Description:
Concrete mix ingredient: Sand

Life Cycle Inventory:
Sand

Product Scope:
Cradle to gate, excludes mixing and pouring impacts

Transportation Distance:
By barge: 0 km*
By container ship: 0 km*
By rail: 0 km*
By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
US: Silica sand (Excavation and processing) ts (2017)

Steel, reinforcing rod **1,233,203.9 kg**

Used in the following Revit families:

ADD.B14	0.6 kg (50 yrs)
ADD.B17	5.5 kg (50 yrs)
ADD.P38	4,560.7 kg (50 yrs)
ADD.S1	3,739.0 kg (50 yrs)
ADD.TG-5	19.1 kg (50 yrs)
ADD.TG-5'	8.6 kg (50 yrs)
Beam Concrete Rectangular Crank	7,166.1 kg (50 yrs)
Beam Concrete-Rectangular	180,753.5 kg (50 yrs)
Bore Pile Dia.600	437,142.7 kg (50 yrs)
BS1	15,144.3 kg (50 yrs)
BS2	4,715.3 kg (50 yrs)
BS3	25,285.7 kg (50 yrs)
BS4	1,302.9 kg (50 yrs)
BS5	9,010.3 kg (50 yrs)
BS6	10,564.1 kg (50 yrs)
CHAM.STP	56.5 kg (50 yrs)
CHAM.STP-1	195.7 kg (50 yrs)
Column Concrete-Rectangular	163,243.4 kg (50 yrs)
Corbel Ramp	271.6 kg (50 yrs)
Corbel Ramp-1	169.2 kg (50 yrs)
CS1	52,571.6 kg (50 yrs)
F1	753.6 kg (50 yrs)
FH.BS3	4,269.6 kg (50 yrs)
FH.BS4	541.3 kg (50 yrs)
GTR.A	2,175.2 kg (50 yrs)
GTR.B	2,473.3 kg (50 yrs)
P1	387.9 kg (50 yrs)
P1'	508.7 kg (50 yrs)
P12	9,518.0 kg (50 yrs)
P13	11,822.4 kg (50 yrs)
P1A'	1,139.8 kg (50 yrs)
P1A"	12,837.2 kg (50 yrs)
P1A.A	1,114.2 kg (50 yrs)
P1B	1,132.7 kg (50 yrs)
P1B'	854.9 kg (50 yrs)

LCI Data (continued)

P2	2,327.2 kg (50 yrs)
P2'.A	1,804.5 kg (50 yrs)
P2-1	664.1 kg (50 yrs)
P38	46,830.4 kg (50 yrs)
P4	2,185.4 kg (50 yrs)
P4-1	2,913.9 kg (50 yrs)
P5	4,022.3 kg (50 yrs)
P5-1	3,824.5 kg (50 yrs)
P5-2	4,097.7 kg (50 yrs)
P6	8,964.1 kg (50 yrs)
P6-1	3,572.1 kg (50 yrs)
P6-2	3,526.8 kg (50 yrs)
P7	4,933.4 kg (50 yrs)
P7-1	3,988.9 kg (50 yrs)
P8	7,929.8 kg (50 yrs)
PON.BLOWER	117.8 kg (50 yrs)
PON.GST	362.0 kg (50 yrs)
PON.PUMP	81.0 kg (50 yrs)
PON.PUMP 2	462.6 kg (50 yrs)
PON.TRAVO	117.4 kg (50 yrs)
S1	80,948.0 kg (50 yrs)
S2	68,178.9 kg (50 yrs)
S3	13,352.8 kg (50 yrs)
SLUDGE	2,352.3 kg (50 yrs)
SS	190.9 kg (50 yrs)

Used in the following Tally entries:
- Cast-in-place concrete, custom mix
- Cast-in-place concrete, structural concrete, 2500 psi
- Cast-in-place concrete, structural concrete, 5000 psi

Description:
Common unfinished tempered steel rod suitable for structural reinforcement (rebar)

Life Cycle Inventory:
100% Steel rebar

Product Scope:
Cradle to gate

Transportation Distance:
By truck: 19 km*

End-of-Life Scope:
70% Recovered
30% Landfilled (inert material)

Module D Scope:
Product has a 16.4% scrap input while remainder is processed and credited as avoided burden.

LCI Source:
GLO: Steel rebar worldsteel (2014)

Structural concrete, 2500 psi, 20% fly ash **1,269,199.3 kg**

Used in the following Revit families:

ADD.B14	4.1 kg (50 yrs)
Beam Concrete-Rectangular	1,269,195.2 kg (50 yrs)

Used in the following Tally entries:
- Cast-in-place concrete, structural concrete, 2500 psi

Description:
Structural concrete, 2500 psi, 20% fly ash. Mix design matches National Ready-Mix Concrete Association (NRMCA) Industry-wide EPD.

Life Cycle Inventory:
Coarse aggregate: 45%, Sand: 36%, Portland cement PCA - EPD: 10%, Water: 7%, Fly ash: 2%, Admixture: <1%

Product Scope:
Cradle to gate
Anchors, ties, and metal accessories outside of scope (<1% mass)

Transportation Distance:
By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
- US: Portland cement PCA/ts (2014)
- DE: Pumice gravel (grain size 4/16) (EN15804 A1-A3) ts (2017)
- DE: Gravel (Grain size 2/32) (EN15804 A1-A3) s (2017)
- DE: Fly ash (EN15804 A1-A3) ts (2017)
- DE: Slag-tap granulate (EN15804 A1-A3) ts (2017)
- DE: Expanded clay (EN15804 A1-A3) ts (2017)
- DE: alcium nitrate ts (2017)
- DE: Sodium ligninsulfonate ts (2017)
- DE: Sodium naphtalene sulfonate [estimated] ts (2017)
- US: Sodium hydroxide (caustic soda) ix (100%) ts (2017)
- US: Colophony (rosin, refined) from CN pine gum rosin ts (2017)
- US: Tap water from groundwater ts (2017)
- US: Electricity grid mix s (2014)
- US: Natural gas mix ts (2014)
- US: Diesel mix at filling station (100% fossil) ts (2014)
- US: Liquefied Petroleum Gas (LPG) (70% propane 30% utane) ts (2014)
- US: Light fuel oil at refinery ts (2014)

Structural concrete, 5000 psi, 20% fly ash **3,273,050.0 kg**

Used in the following Revit families:

ADD.B17	39.0 kg (50 yrs)
ADD.P38	32,366.4 kg (50 yrs)
ADD.S1	26,534.9 kg (50 yrs)
ADD.TG-5	135.8 kg (50 yrs)
ADD.TG-5'	60.7 kg (50 yrs)
Beam Concrete Rectangular Crank	50,856.9 kg (50 yrs)
Beam Concrete-Rectangular	3,607.4 kg (50 yrs)
BS1	107,477.4 kg (50 yrs)
BS2	33,463.8 kg (50 yrs)
BS3	179,449.2 kg (50 yrs)
BS4	9,246.9 kg (50 yrs)
BS5	63,945.0 kg (50 yrs)
BS6	74,972.3 kg (50 yrs)
CHAM.STP	401.1 kg (50 yrs)
CHAM.STP-1	1,388.9 kg (50 yrs)
Column Concrete-Rectangular	63,173.0 kg (50 yrs)
Corbel Ramp	1,157.9 kg (50 yrs)
CS1	373,094.0 kg (50 yrs)
F1	5,348.2 kg (50 yrs)
FH.BS3	30,300.9 kg (50 yrs)
FH.BS4	3,841.6 kg (50 yrs)
GTR.A	15,436.8 kg (50 yrs)
GTR.B	17,553.0 kg (50 yrs)
P1	2,752.7 kg (50 yrs)
P1'	3,610.0 kg (50 yrs)
P12	67,547.8 kg (50 yrs)
P13	83,902.4 kg (50 yrs)
P1A'	8,089.2 kg (50 yrs)
P1A"	91,104.4 kg (50 yrs)
P1A.A	7,907.2 kg (50 yrs)
P1B	8,038.6 kg (50 yrs)
P1B'	6,066.9 kg (50 yrs)
P2	16,515.9 kg (50 yrs)
P2'.A	12,806.6 kg (50 yrs)
P2-1	4,713.1 kg (50 yrs)
P38	332,349.3 kg (50 yrs)
P4	15,509.8 kg (50 yrs)
P4-1	20,679.7 kg (50 yrs)
P5	28,546.0 kg (50 yrs)
P5-1	27,142.1 kg (50 yrs)
P5-2	29,080.9 kg (50 yrs)
P6	63,616.9 kg (50 yrs)
P6-1	25,350.5 kg (50 yrs)
P6-2	25,029.6 kg (50 yrs)
P7	35,011.5 kg (50 yrs)
P7-1	28,308.7 kg (50 yrs)
P8	56,276.5 kg (50 yrs)
PON.BLOWER	835.7 kg (50 yrs)
PON.GST	2,568.8 kg (50 yrs)
PON.PUMP	575.2 kg (50 yrs)
PON.PUMP 2	3,283.1 kg (50 yrs)
PON.TRAVO	833.4 kg (50 yrs)
S1	574,478.1 kg (50 yrs)
S2	483,856.9 kg (50 yrs)

LCI Data (continued)

S3	94,763.2 kg (50 yrs)
SLUDGE	16,693.6 kg (50 yrs)
SS	1,354.9 kg (50 yrs)

Used in the following Tally entries:
Cast-in-place concrete, structural concrete, 5000 psi

Description:
Structural concrete, 5000 psi, 20% fly ash. Mix design matches National Ready-Mix Concrete Association (NRMCA) Industry-wide EPD.

Life Cycle Inventory:
Coarse aggregate: 41%, Sand: 30%, Portland cement PCA - EPD: 17%, Water: 7%, Fly ash: 4%, Admixture: <1%

Product Scope:
Cradle to gate
Anchors, ties, and metal accessories outside of scope (<1% mass)

Transportation Distance:
By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
US: Portland cement PCA/ts (2014)
DE: Pumice gravel (grain size 4/16) (EN15804 A1-A3) ts (2017)
DE: Gravel (Grain size 2/32) (EN15804 A1-A3) s (2017)
DE: Fly ash (EN15804 A1-A3) ts (2017)
DE: Slag-tap granulate (EN15804 A1-A3) ts (2017)
DE: Expanded clay (EN15804 A1-A3) ts (2017)
DE: alcium nitrate ts (2017)
DE: Sodium ligninsulfonate ts (2017)
DE: Sodium naphtalene sulfonate [estimated] ts (2017)
US: Sodium hydroxide (caustic soda) ix (100%) ts (2017)
US: Colophony (rosin, refined) from CN pine gum rosin ts (2017)
US: Tap water from groundwater ts (2017)
US: Electricity grid mix s (2014)
US: Natural gas mix ts (2014)
US: Diesel mix at filling station (100% fossil) ts (2014)
US: Liquefied Petroleum Gas (LPG) (70% propane 30% utane) ts (2014)
US: Light fuel oil at refinery ts (2014)

Water **376,918.6 kg**

Used in the following Revit families:

Bore Pile Dia.600	278,434.8 kg (50 yrs)
Column Concrete-Rectangular	98,306.9 kg (50 yrs)
Corbel Ramp	69.1 kg (50 yrs)
Corbel Ramp-1	107.7 kg (50 yrs)

Used in the following Tally entries:
Cast-in-place concrete, custom mix

Description:
Concrete mix ingredient: Tap water

Life Cycle Inventory:
Tap water

Product Scope:
Cradle to gate, excludes mixing and pouring impacts

Transportation Distance:
By truck: 19 km*

End-of-Life Scope:
55% Recycled into coarse aggregate
45% Landfilled (inert material)

Module D Scope:
Avoided burden credit for coarse aggregate, includes grinding energy

LCI Source:
US: Tap water from groundwater ts (2017)

LAMPIRAN D

PROSES PENGINPUTAN DATA PADA TALLY

Object of Study

Pilih Tipe Objek Penelitian :
a. *Full Building Study*
b. *Design Option Comparison*
c. *Define Template File*

Pemilihan Kategori, Fase, dan Model yang digunakan

Pilih Kategori :
a. Ceilings
b. Curtainwall Mullions
c. Curtainwall Panels
d. Doors
e. Floors (Pelat lantai)
f. Roofs
g. Stairs and Railing
h. Structure (Mencakup balok, kolom, tie beam, pile cap dan pondasi)
i. Walls
j. Windows

Project Browser

Menampilkan *Family* :
a. Floors
b. Structural Column
c. Structural Beam
d. Structural Foundation (Tie Beam dan Pondasi)

Serta tipe-tipe nya serta material penyusunnya:
a. *Concrete* fc' 35 MPa
b. *Concrete* fc' 30 MPa
c. *Concrete* fc' 25 MPa
d. *Concrete* fc' 15 MPa

Edit Definition (1)

Pilih Material :
a. Concrete
b. Masonry
c. Metals
d. Wood/Plastics/Composites
e. Thermal and Moisture Protection
f. Openings and Glazing
g. Finishes

Edit Definition (2)

Pilih *Concrete* :
a. Cast-in-place Concrete
b. Concrete Reinforcement
c. Glass Fiber Reinforcement Concrete
d. Precast Concrete
e. Stair

Edit Definition (2)

Pilih *Cast-in-place Concrete* :
a. Custom Mix
b. Lightweight structural concrete, 3000 psi
c. Lightweight structural concrete, 4000 psi
d. Lightweight structural concrete, 5000 psi
e. Structural concrete, 2500 psi
f. Structural concrete, 3000 psi
g. Structural concrete, 4000 psi
h. Structural concrete, 5000 psi
i. Structural concrete, 6000 psi
J. Structural concrete, 8000 psi

Define Component and Quantity Take Off

Input pada *Custom Mix* :
a. Cement
b. Aggregate
c. Sand
d. Water
e. Admixture
f. Add-ins
g. Expanded Shale
h. Expanded Slag
i. Fly Ash
j. Glass Fibers
k. Reinforcement

Input Pada *Structural Concrete* 2500 psi dan 5000 psi :
a. Concrete Type
b. Reinforcement

Report Details (1)

Input pada *Report Information* :
a. Title
b. Date
c. Author
d. Company
e. Project
f. Location
g. Cover
h. Gross Building Area
i. Expected Building Life
j. Goal and Scope Assessment

Report Details (2)

Input pada *Transportation Impacts (Edit Transportation Distance)* sesuai material masing-masing:
a. Truck
b. Container
c. Rail
d. Barge

Report Details (3)

Pilih *Biogenic Carbon*
a. Include Biogenic Carbon
b.Exclude Biogenic Carbon

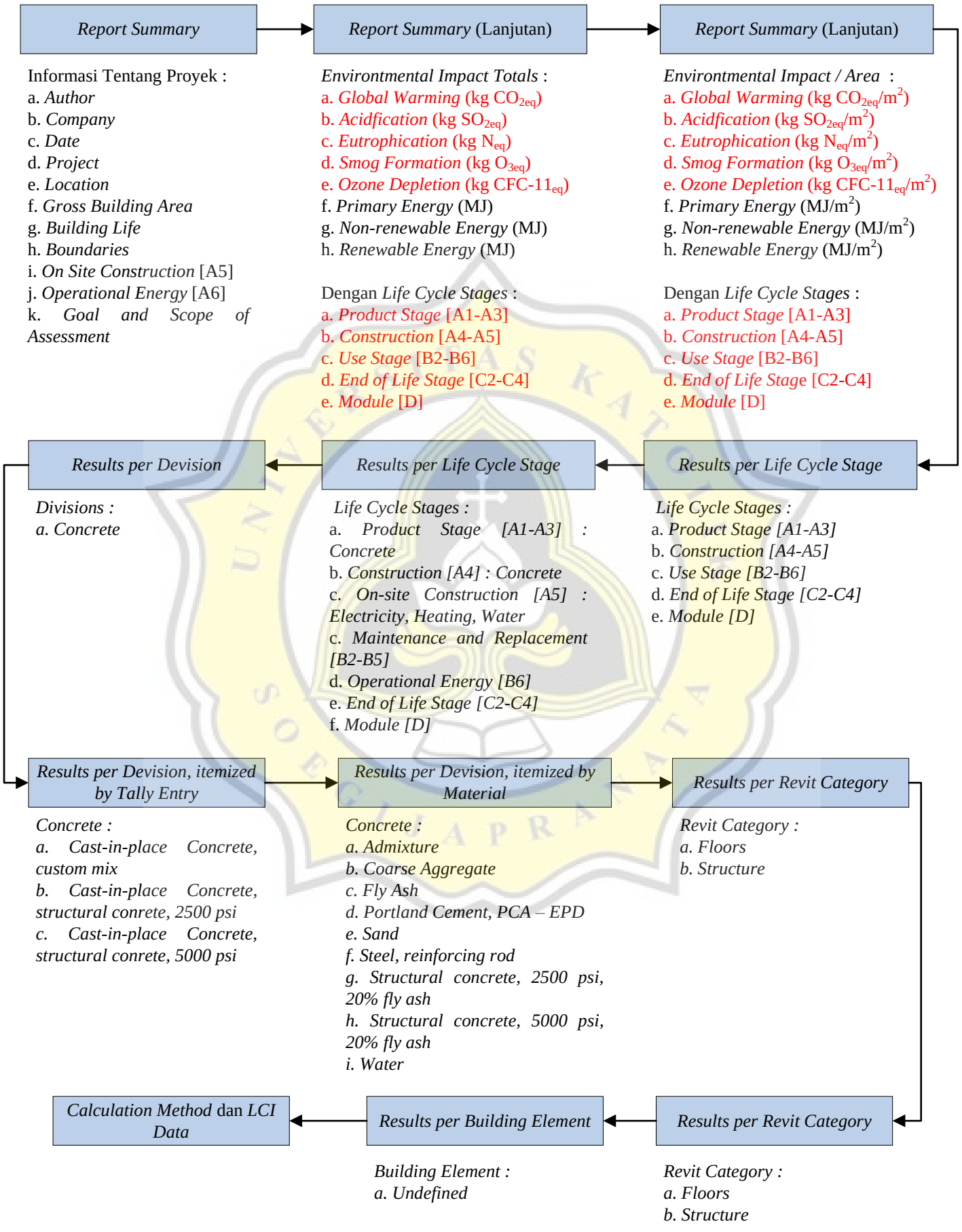
Pilih *Output Summaries* :
a. Bill of Materials
b. Contribution Assessment (Life Cycle Stage, Division, Revit Category, Building Element)

Report Details (4)

Input Construction Impact :
a. Electricity
b.Heating
c.Water

Input *Operational Energy Impacts* :
a.Electicity
b.Heating

HASIL *LIFE CYCLE ASSESSMENT* DENGAN MENGGUNAKAN TALLY



PROSES PENGINPUTAN DATA PADA ONECLICK LCA

Data

Input Otomatis :
a. *LCA in Revit*
b. *LCA in Cloud*

Input Manual :
Pilih Review Manually atas tahapan selanjutnya.

Settings

Input Informasi Proyek :
1. Nama Proyek
2. Input Desain
a. Desain yang sudah tersimpan
b. Desain baru
3. Penggunaan *Tool*
Life-Cycle Assessment EN-15978

Settings (Lanjutan)

4. *Filtering Settings*
a. Structure and envelope (LEED)
b. Building without building technology (BREEAM/HQE/YM)
c. Building; no systems or openings
d. Building without external areas or technology (NS3720/DGNB)
e. Building without external areas
f. All data
g. Infrastructure (all data)
h. Choose data group manually

Settings (Lanjutan)

5. *Existing Data Preservation*
a. Replace existing data with imported data
b. Add import to the existing data
c. Only update the quantities from the import

Untuk Desain Baru :
1. Nama Proyek
2. Deskripsi Proyek

Settings (Lanjutan)

3. Tahapan *Project Life-Cycle* yang Ditinjau
a. 0 – Strategic Definition
b. 1 – Preparation and Brief / Programming
c. 2 – Concept Design / Schematic Design
d. 3 – Developed Design / Design Development
e. 4 – Technical Design / Preparation of Construction Documents
f. 5 – Construction / Hiring the Contractor-Construction Administrstion
g. 6 - Handover and Close Out / Project Close Out
h. 7 – In Use
i. 8 – Component only (not whole building)

Settings (Lanjutan)

4. *Tools* yang Digunakan
a. Life-cycle assessment, EN-15978
b. Building Circularity

5. *Scope* dan Tipe Analisis
a. New construction, whole building
b. Renovation of an existing building
c. Expansion of an existing building
d. Interior design project
e. Component evaluation only
f. Other type of analysis

Classify

Pengelompokkan komponen (yang teridentifikasi) berdasarkan kesamaannya menjadi kelompok baru. Pondasi, Kolom, Balok, Pelat ke dalam :
a. Foundation
b. Refrigerants
c. External Wall
d. Column
e. Internal Wall
f. Beam
g. Door
h. Window
i. Finish
j. Other

Filter

Berdasarkan Classify yang telah didefinisikan, melakukan pemilihan komponen (disertai informasi kuantitas) yang disertakan dalam import data.
a. Column
b. Beam
c. Slab
d. External Wall
e. Foundation
f. Stairs
g. Other
h. Surface

Settings (Lanjutan)

6. *Frame Type* / Rangka Bangunan
a. Not determined / not sure
b. Concrete frame
c. Steel frame
d. Timber frame
e. Other / mixed frame
f. Existing frame
g. Not applicable

7. Komponen Bangunan yang Diikutsertakan dalam Analisis
a. Foundations and substructure
b. Structure and enclosure
c. Finishing and other materials
d. External areas
e. Services

Combine

Pengelompokan komponen ke dalam kelompok yang sama berdasarkan beberapa kriteria :
a. Class
b. Material
c. Composite
d. Type
e. Material Group
f. Thickness
dll

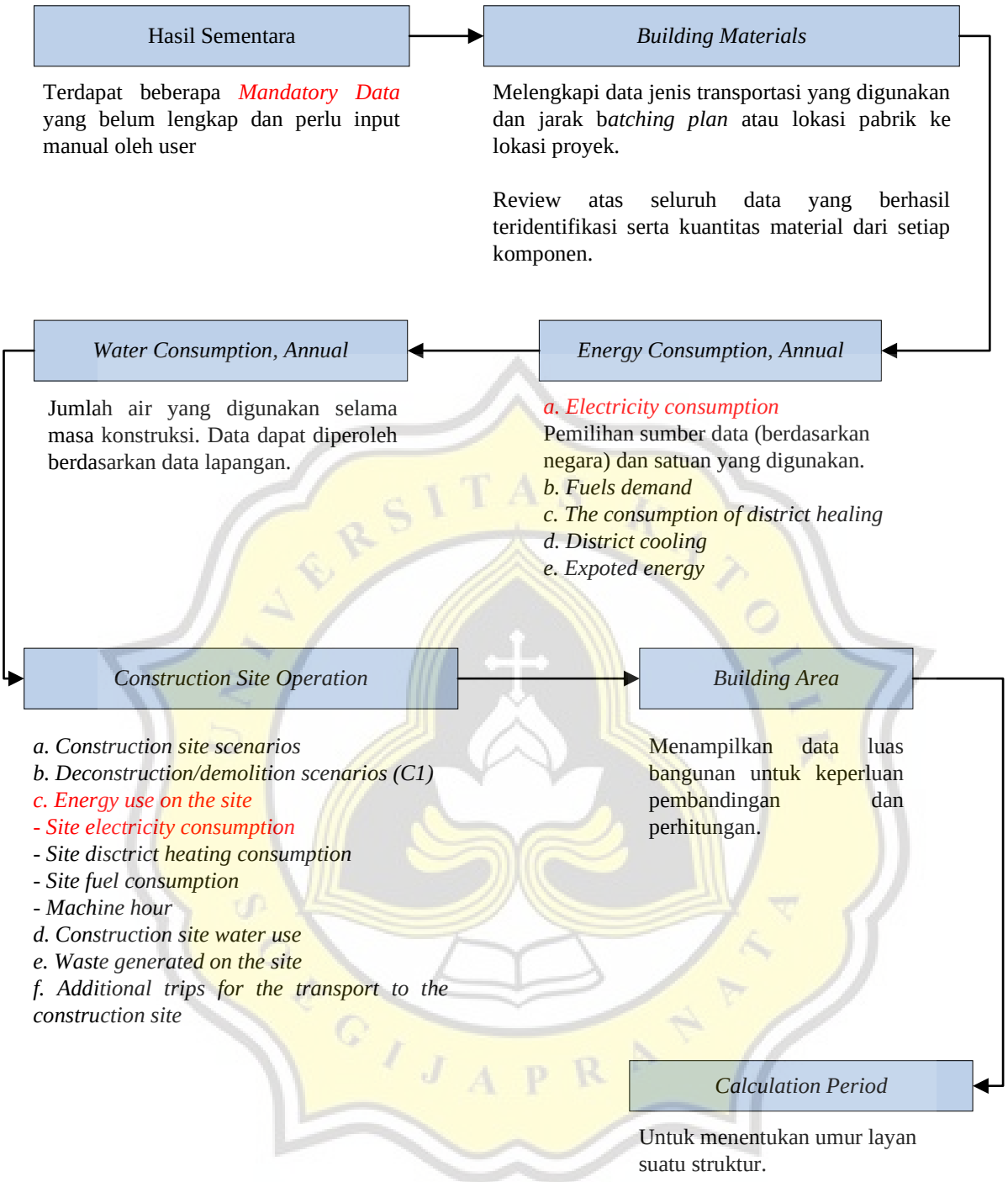
Review

Review atas komponen, *class* dan kuantitas yang akan/tidak diikutsertakan dalam analisis.

Mapping

Resume data yang berhasil teridentifikasi oleh *software*.
Penyesuaian atas data yang teridentifikasi

PROSES MELENGKAPI DATA PADA ONECLICK LCA



HASIL *LIFE CYCLE ASSESSMENT* DENGAN MENGGUNAKAN ONECLICK LCA