Brightcon 2026, September 23rd, 2026

Reconciling stochastic foregrounds with stochastic backgrounds in LCA

a framework applied to natural hazards in LCA

Xavier Tanguay, Ben Amor

LIRIDE
Interdisciplinary Reserach Laboratory in
Life Cycle Assessment and Circular Economy

Agenda

I. Context

II. Research gaps and objective

III. Coupling framework

IV. Case studies

V. Demonstration

VI. Outlooks

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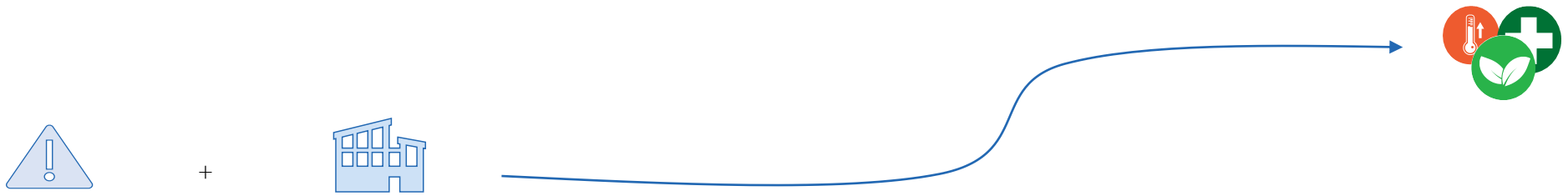
Context



Natural hazards + Built environment

Environmental impacts

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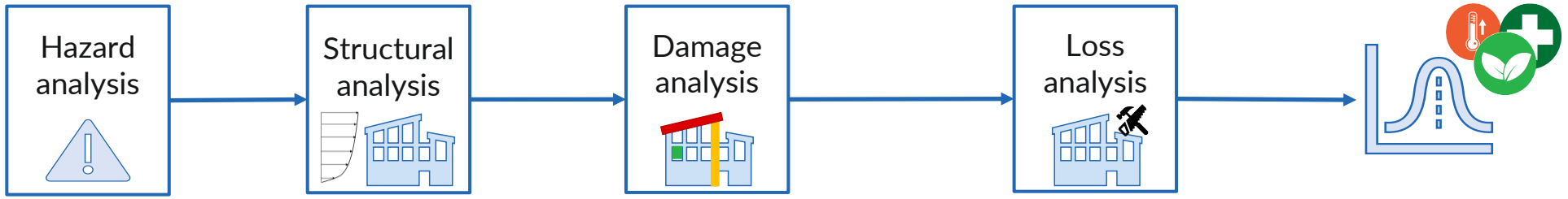
Context

Asset performance assessment workflows :

- convert engineering concerns to indicators relevant for decision-making (Moehle and Deierlin, 2004)



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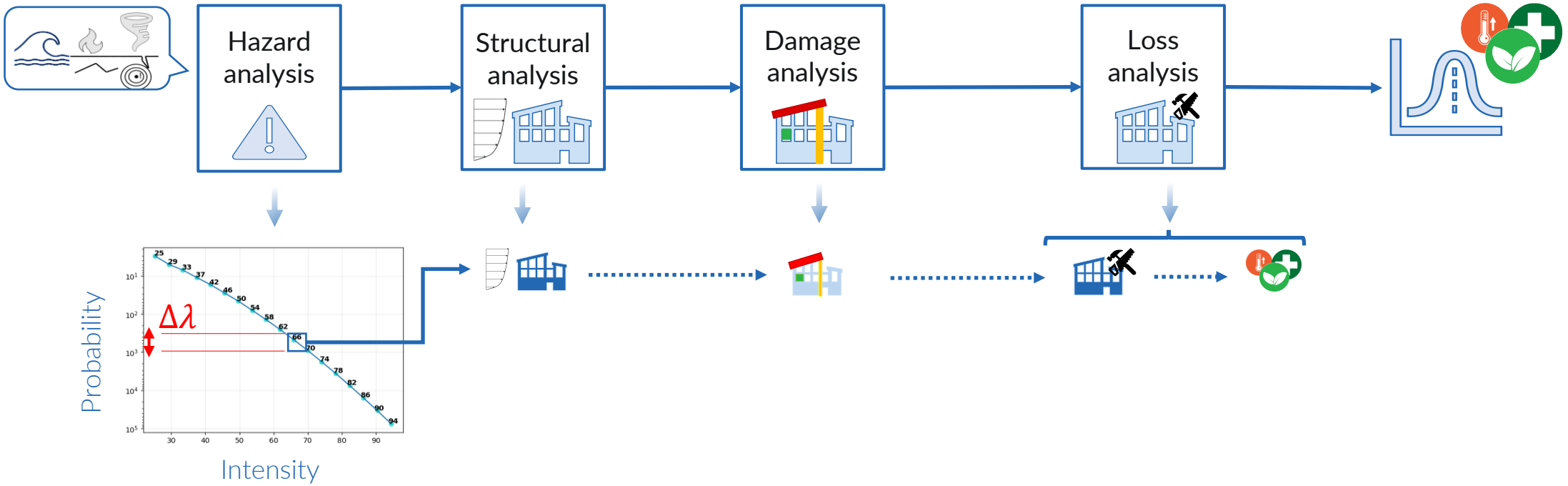

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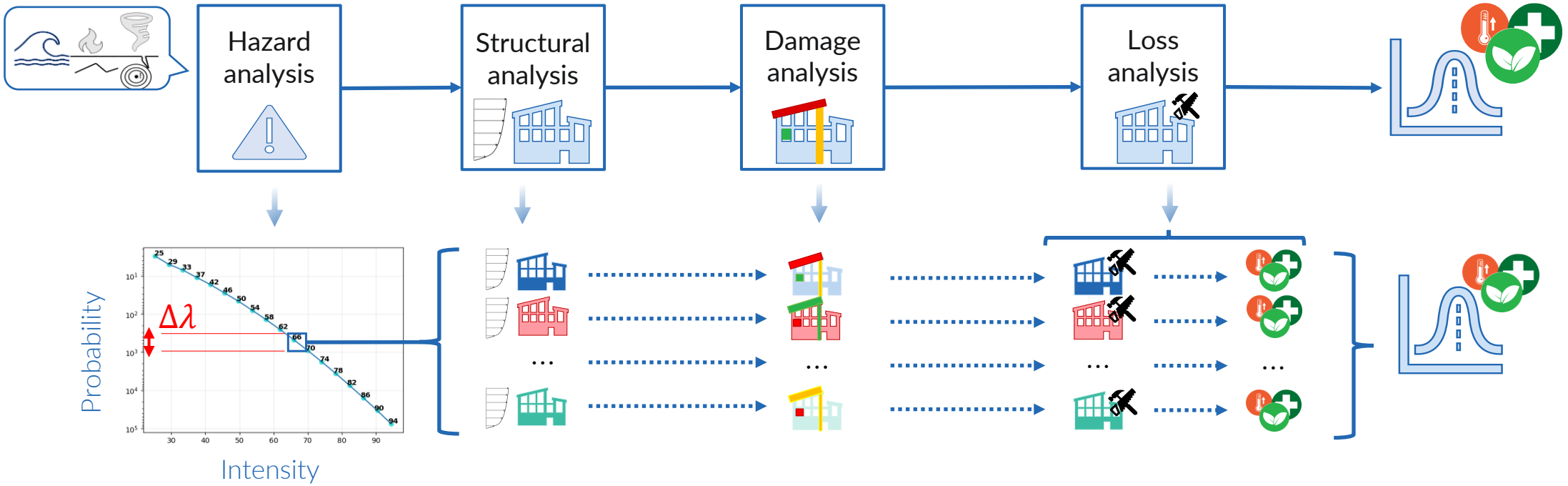

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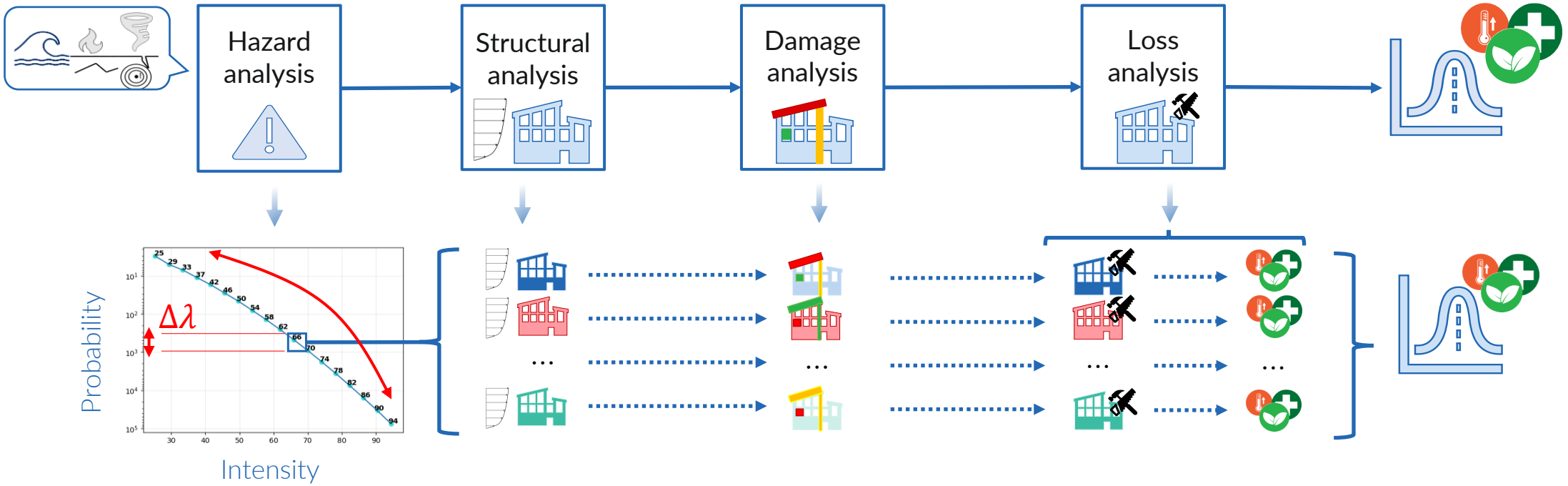

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Research gaps and objective

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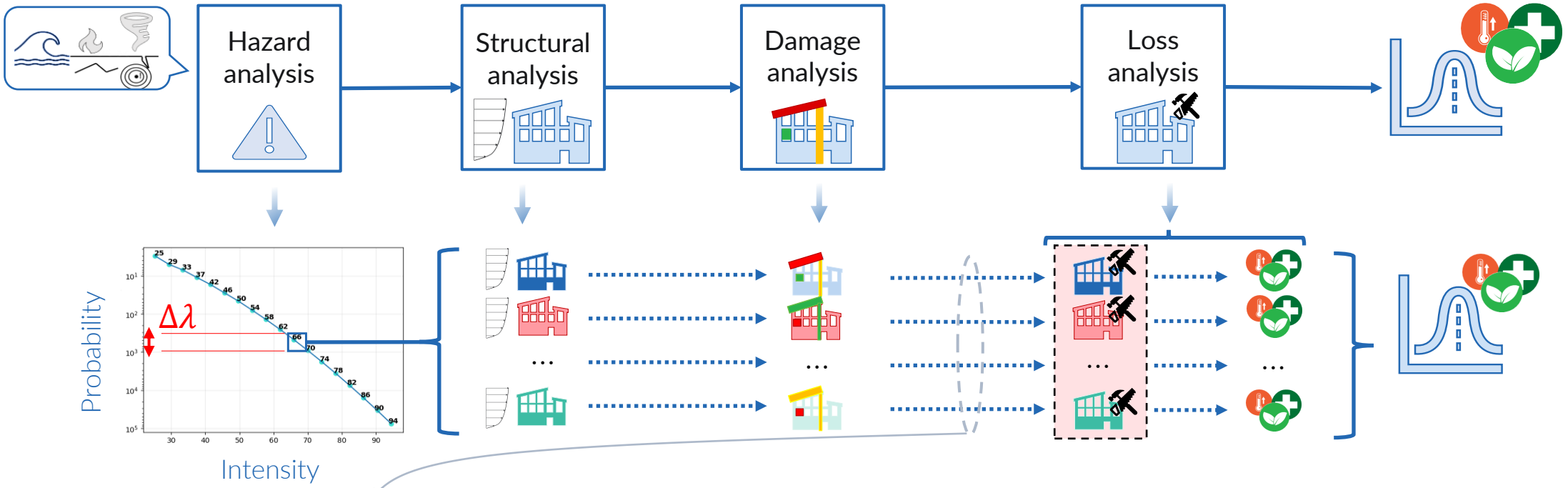

Need to process:

- Granular inputs that lack distributions;
- Many samples.

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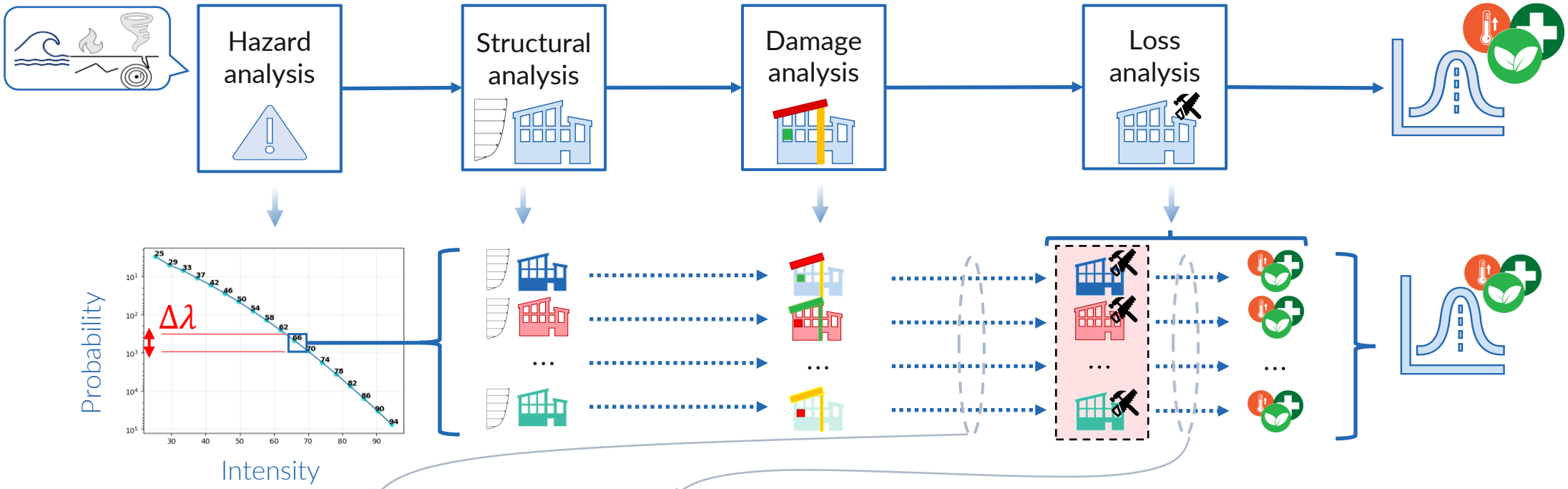

Need to process:

- Granular inputs that lack distributions;
- Many samples.

Expected output:

- Same level of granularity;
- Propagation of LCA uncertainty

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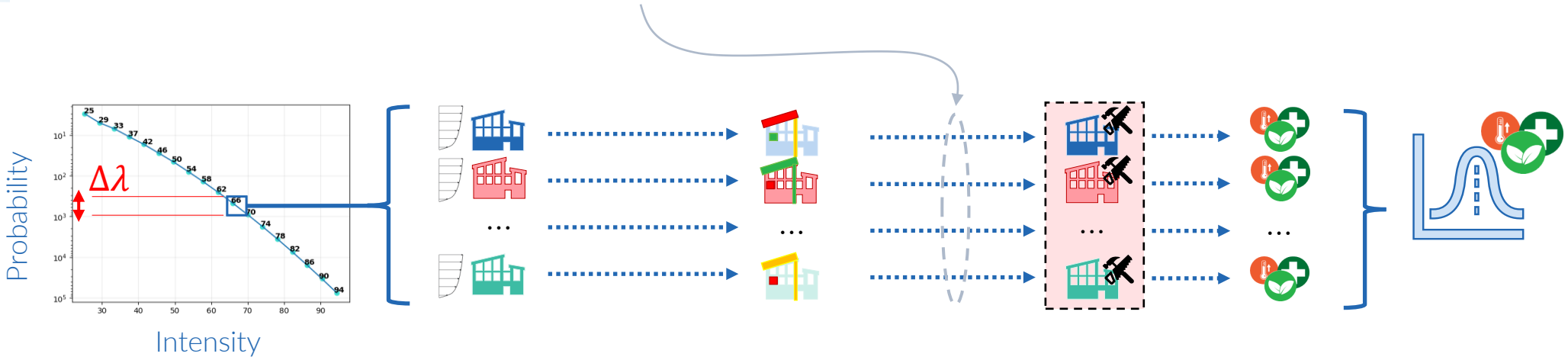
Research gaps and objective

A naïve implementation : a single set of presampling (datapackages in Brightway2.5)



12 000 samples x 18 intensity levels = 216 000 samples

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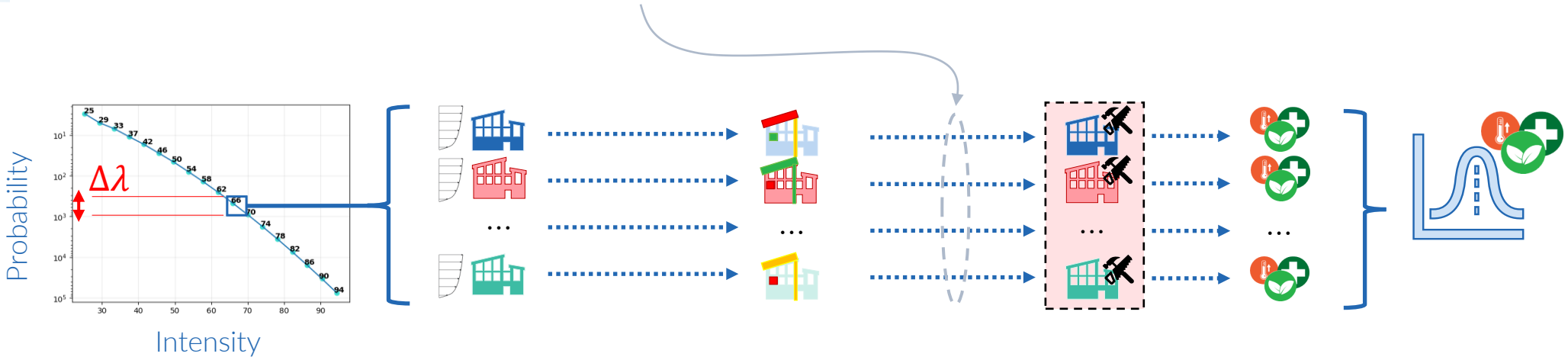

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❌ Estimated simulation time (128 Go of RAM, 16 cores) : ± 20 hours ;
❌ Results are single use (new samples require re-processing everything).

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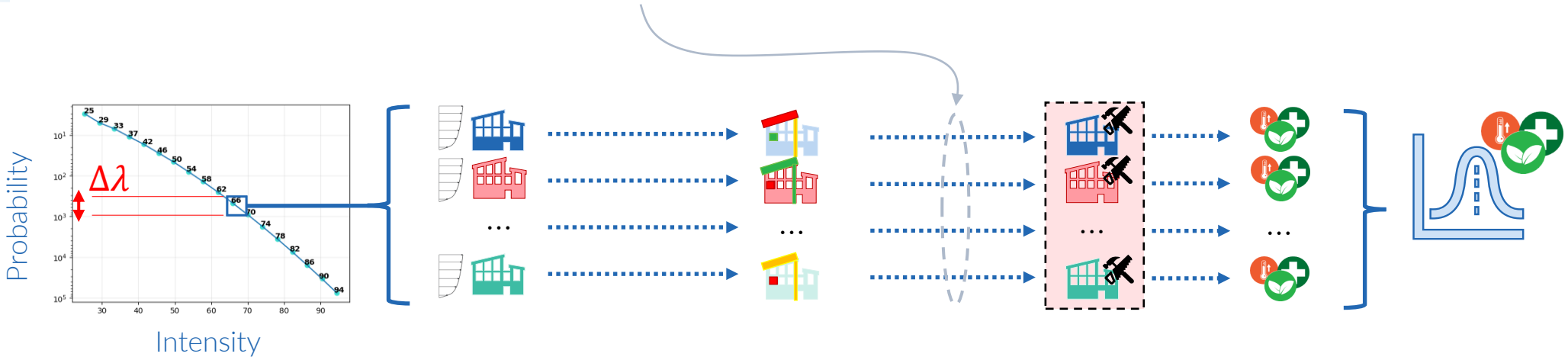

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Objective :
To develop a methodology efficiently forwarding stochastic inputs to an LCA while retaining access to uncertainty propagation capabilities for the LCA itself

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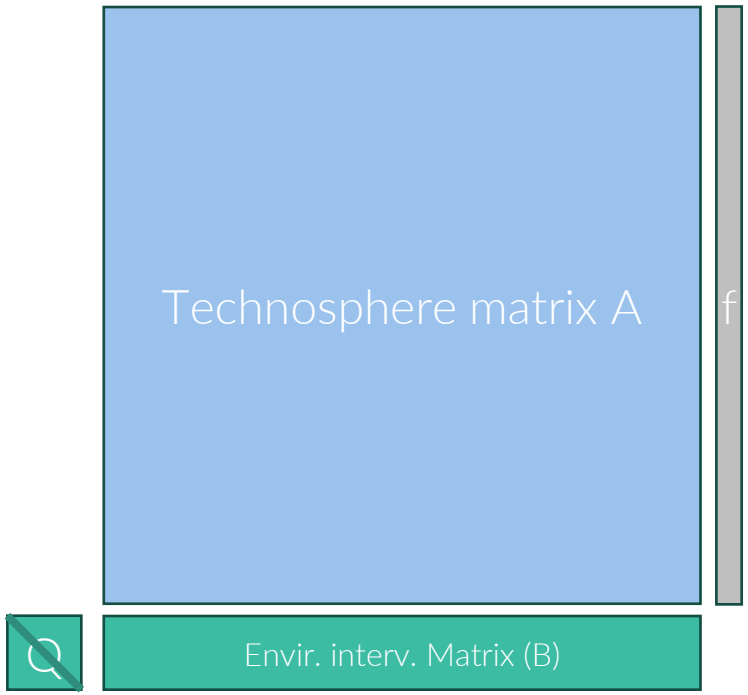
Coupling framework

Dual presampling :



$$h = Q \cdot B \cdot A^{-1} \cdot f$$

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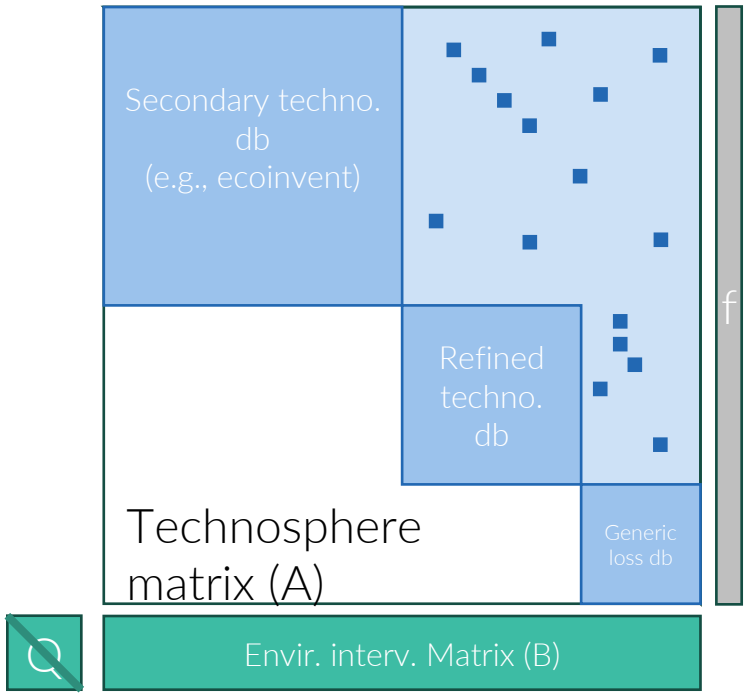
Coupling framework

Dual presampling :



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Coupling framework

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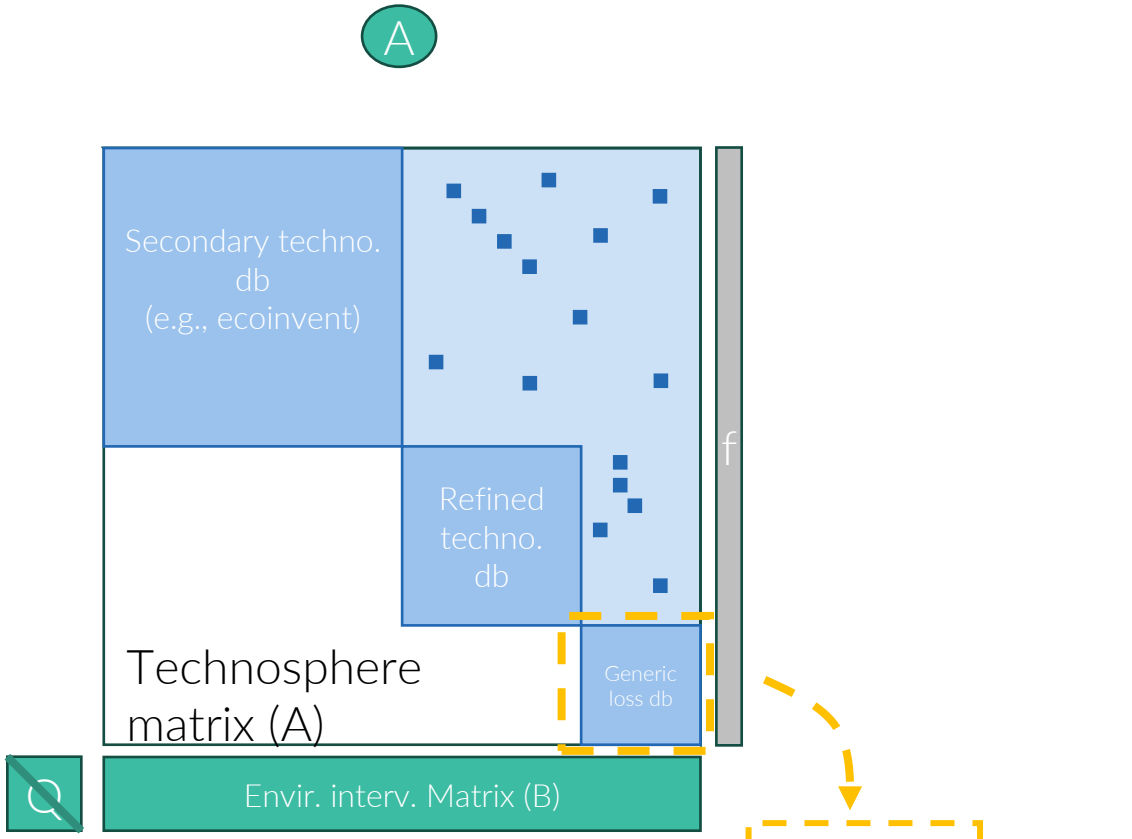

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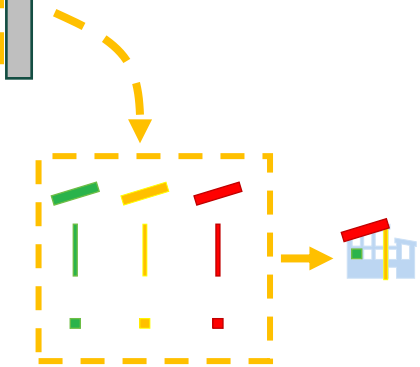

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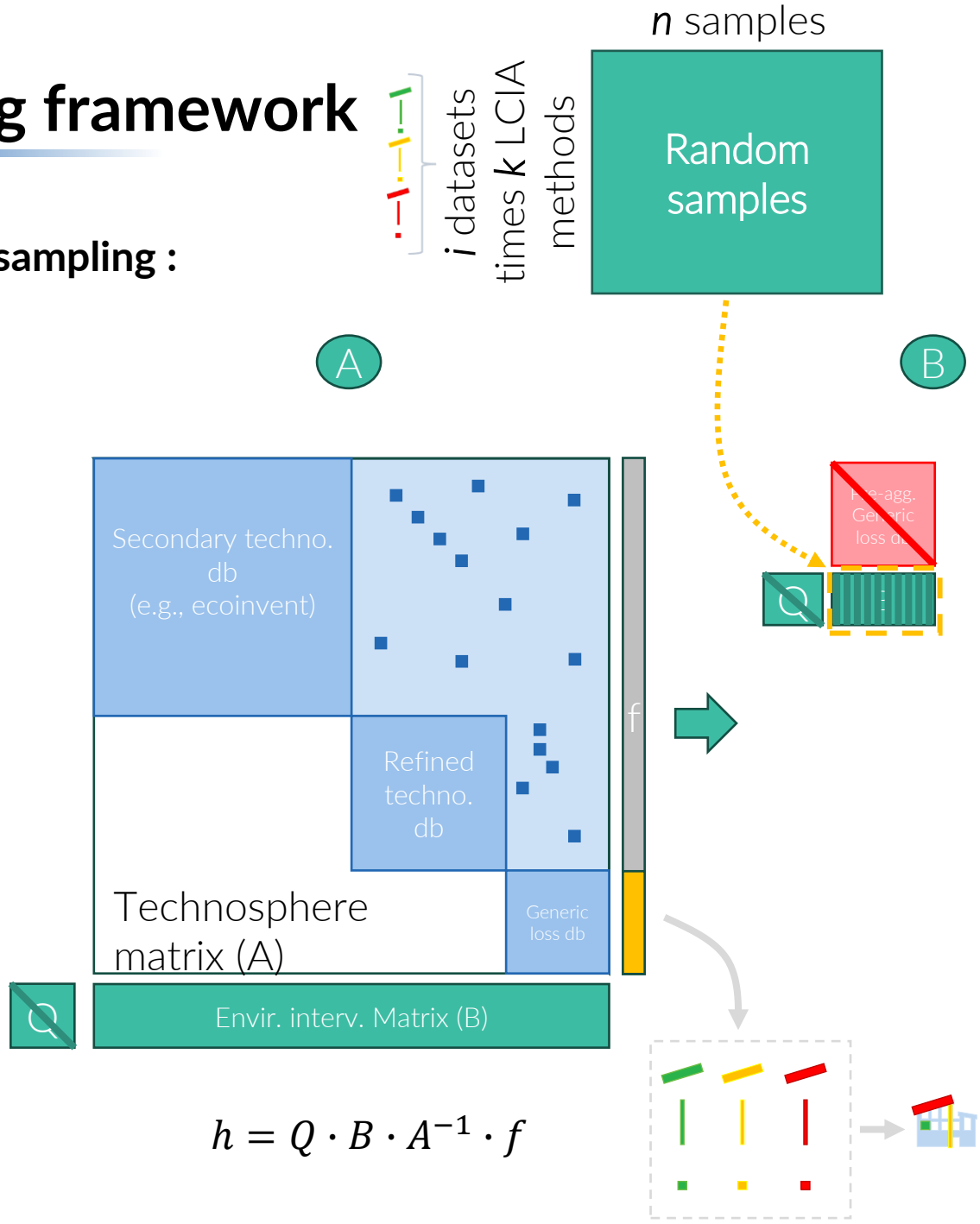

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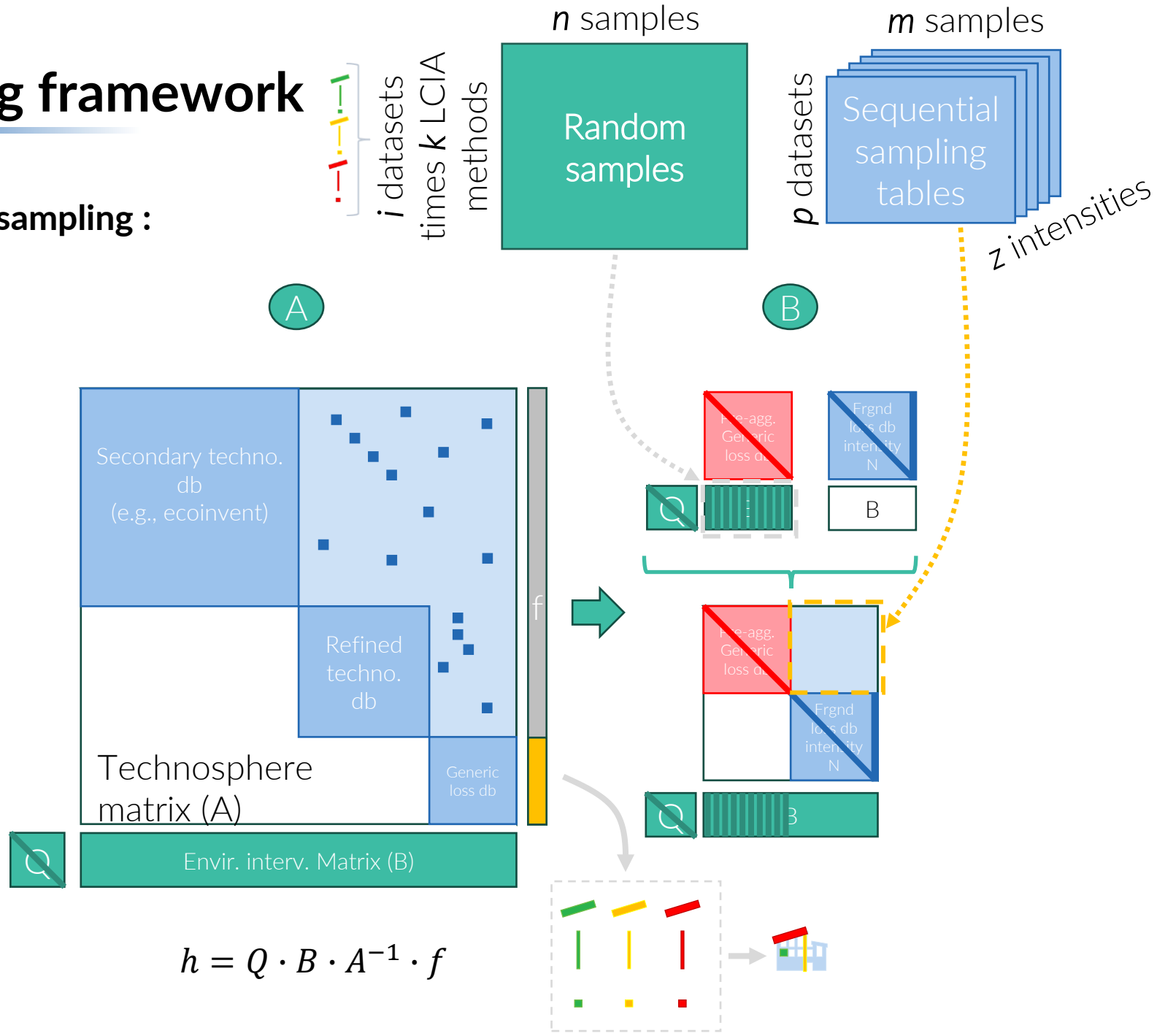

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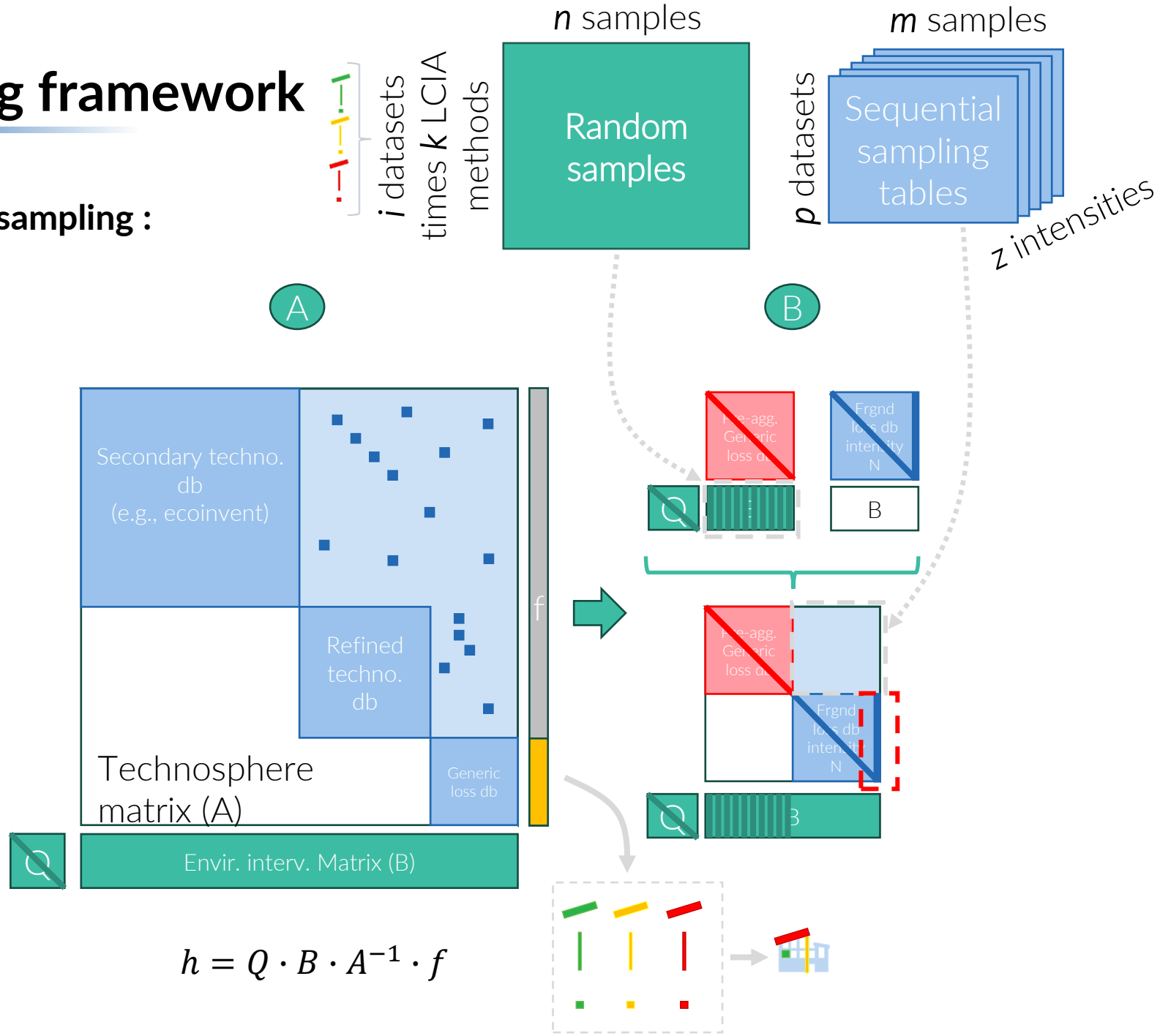

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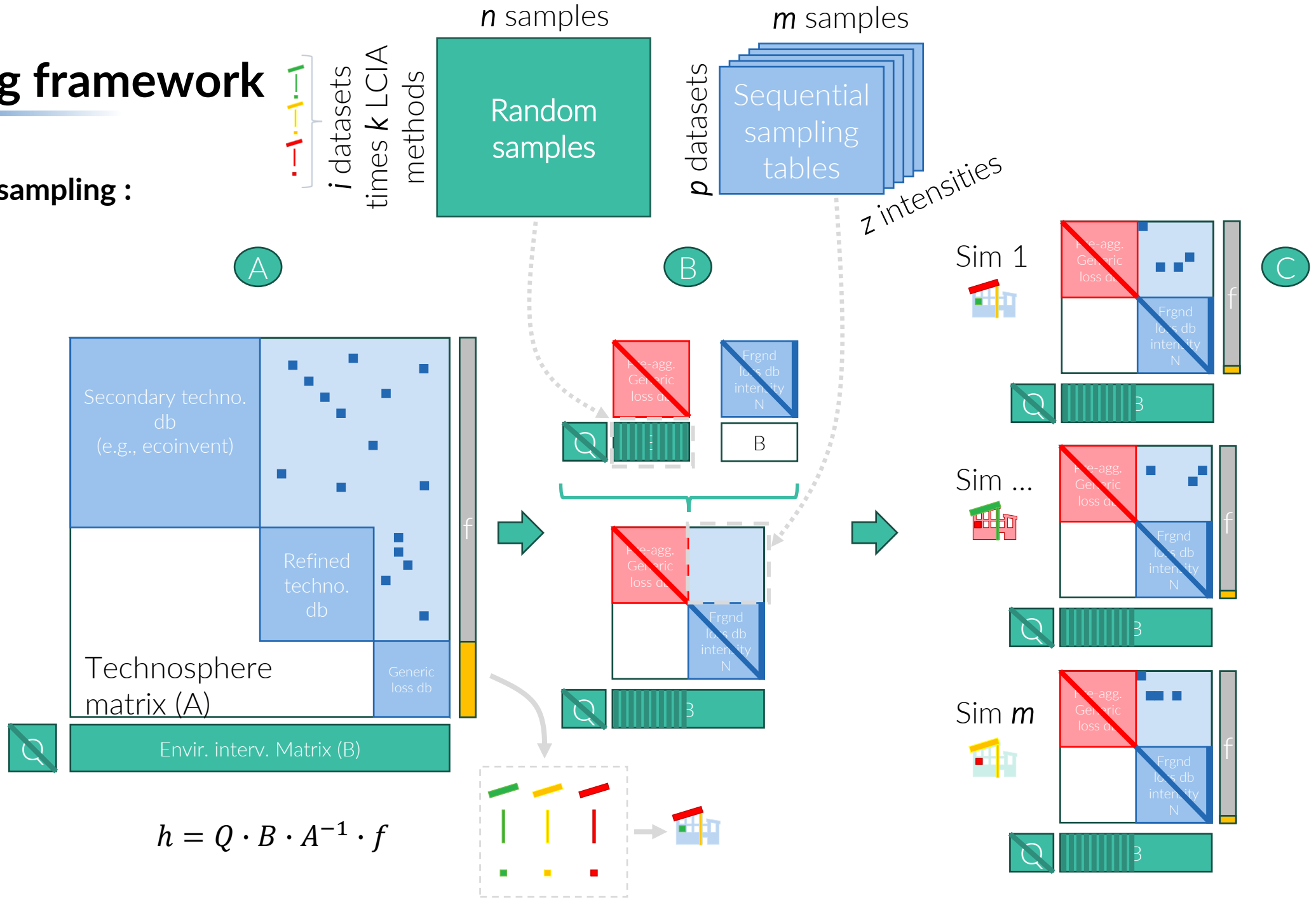

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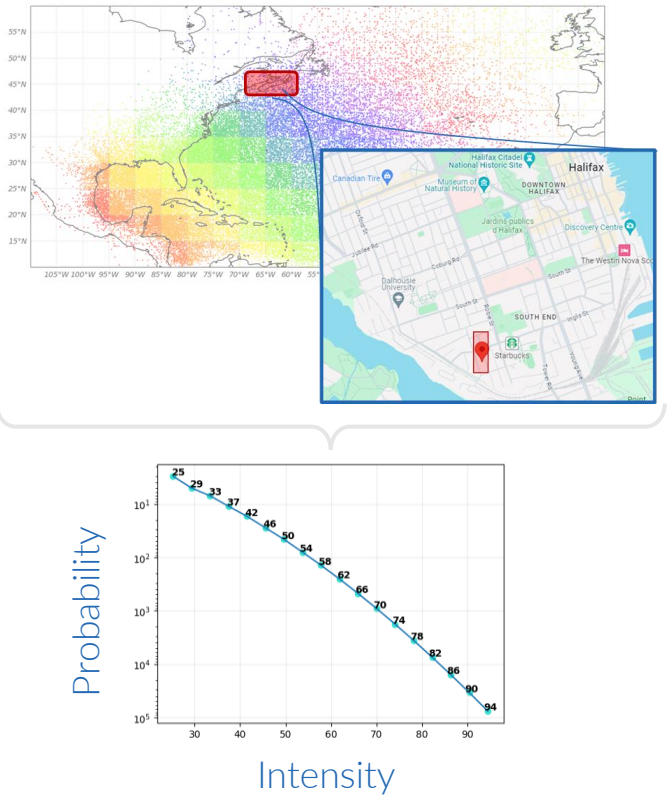
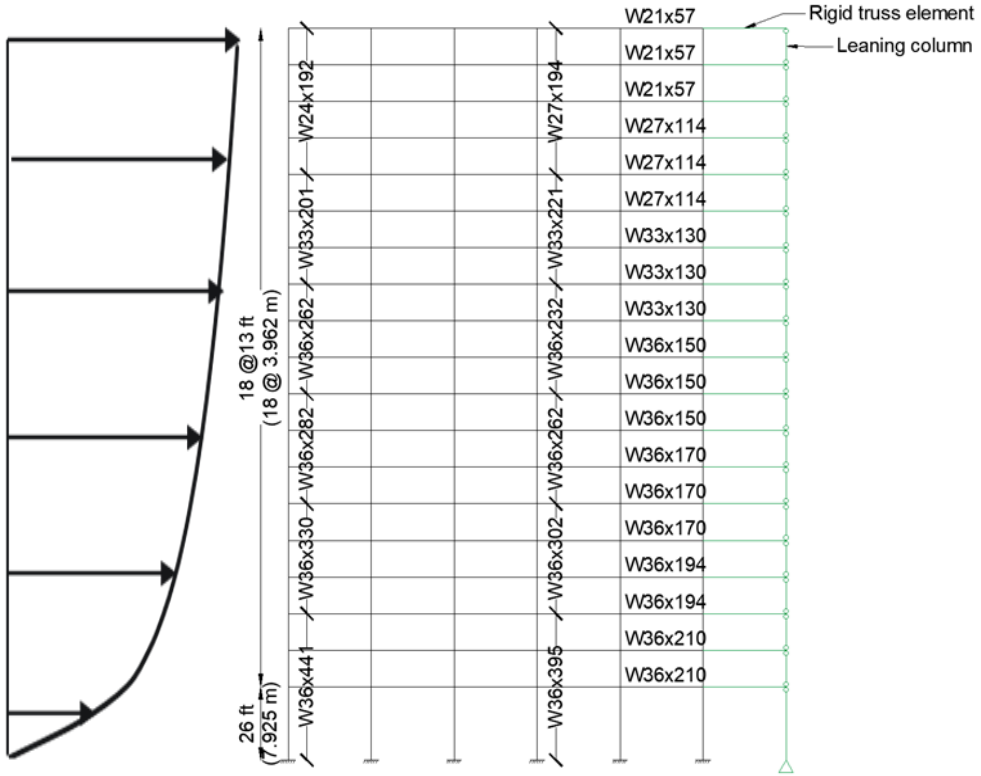
Case studies

Hurricane hazard



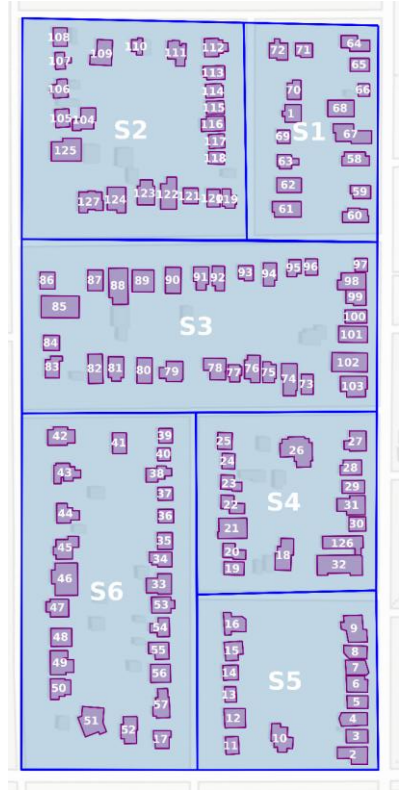
Halifax, Nova-Scotia (Canada)
(Vickery et al., 2009,
Snaiki and Wu., 2018)

a) Individual building



19 storey office building
(adapted from Guan et al 2020)

b) Portfolio of buildings



127 residential buildings
(grouped in sectors S1 to S6)

Demonstration

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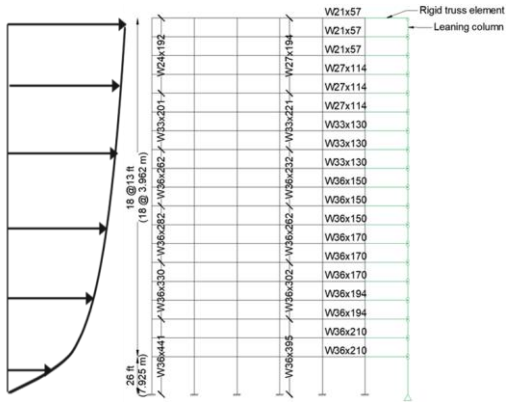
Demonstration

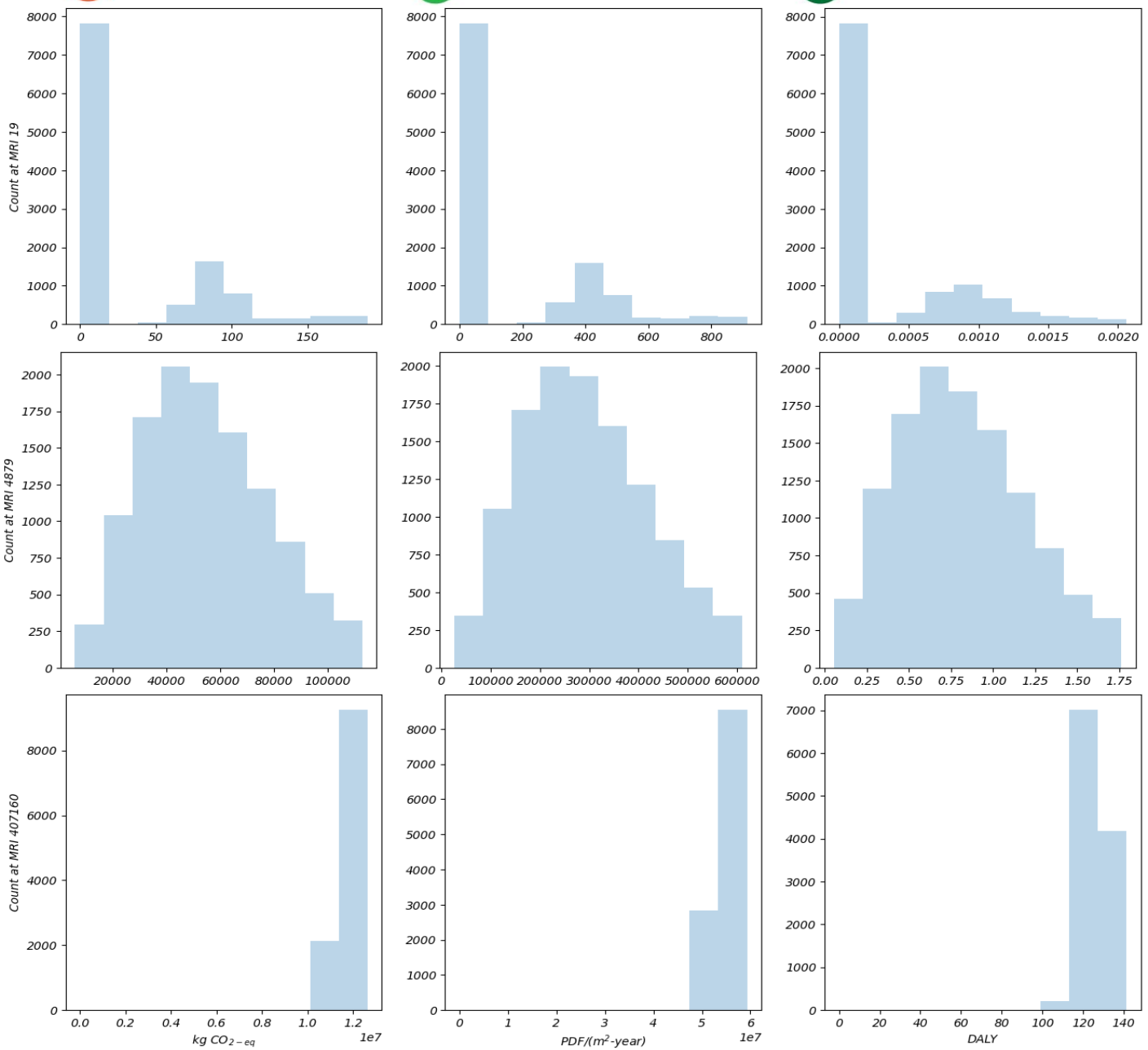
Sample outputs:



IPCC GWP100

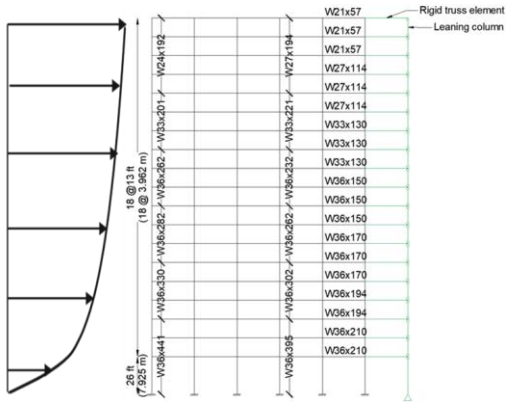
IW+ 2.2.1 Ecosystem Quality

IW+ 2.2.1 Human health

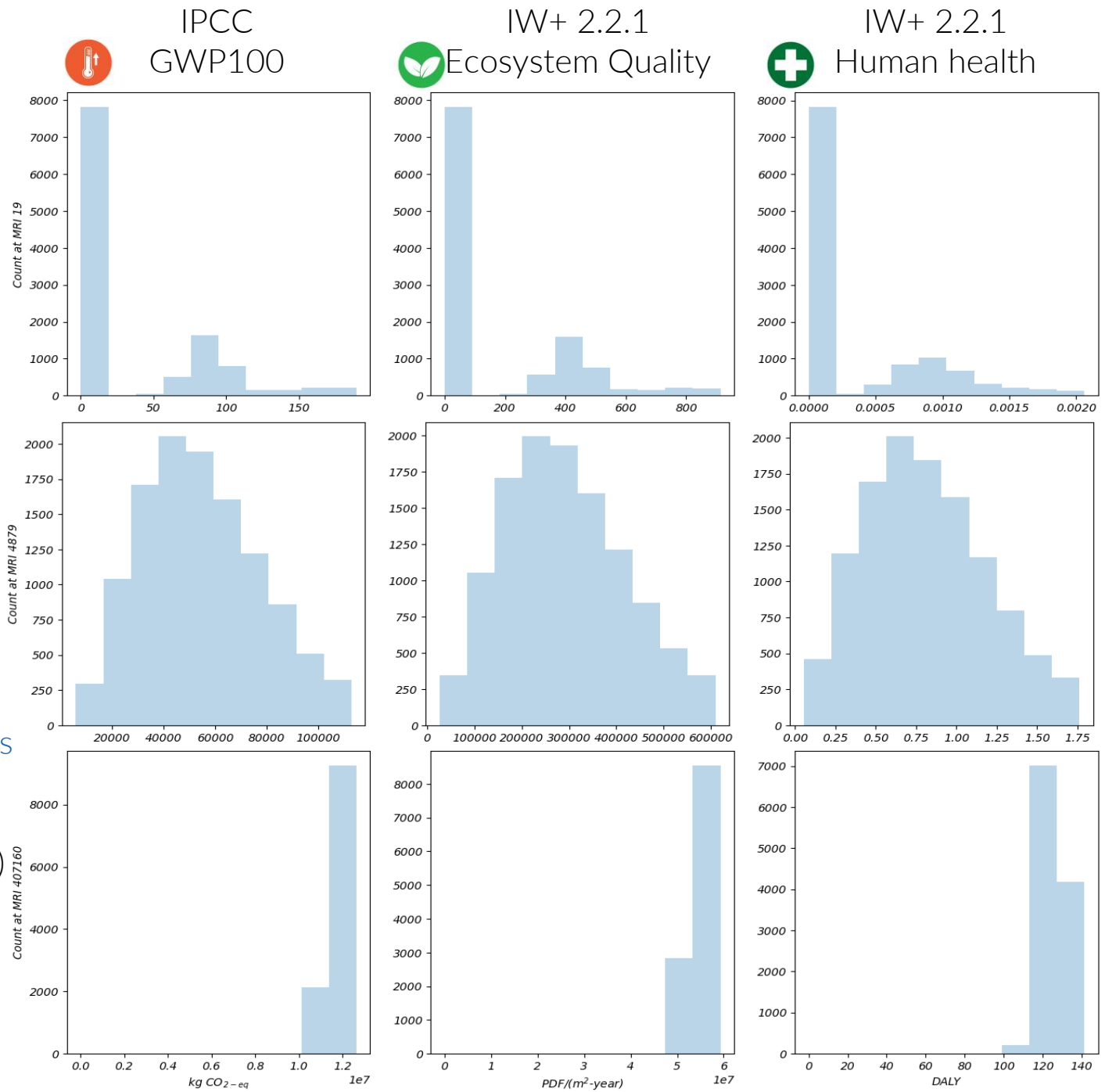


Demonstration

Sample outputs:



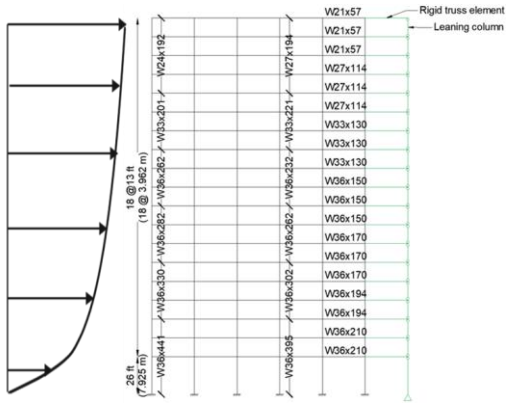
- Pre-aggregation time: <3 hours*
- Simulation time required ≈ 10 minutes
- Can be reused with new samples (e.g., new designs, other hazards, etc.)



*takes longer with the inclusion of balancers

Demonstration

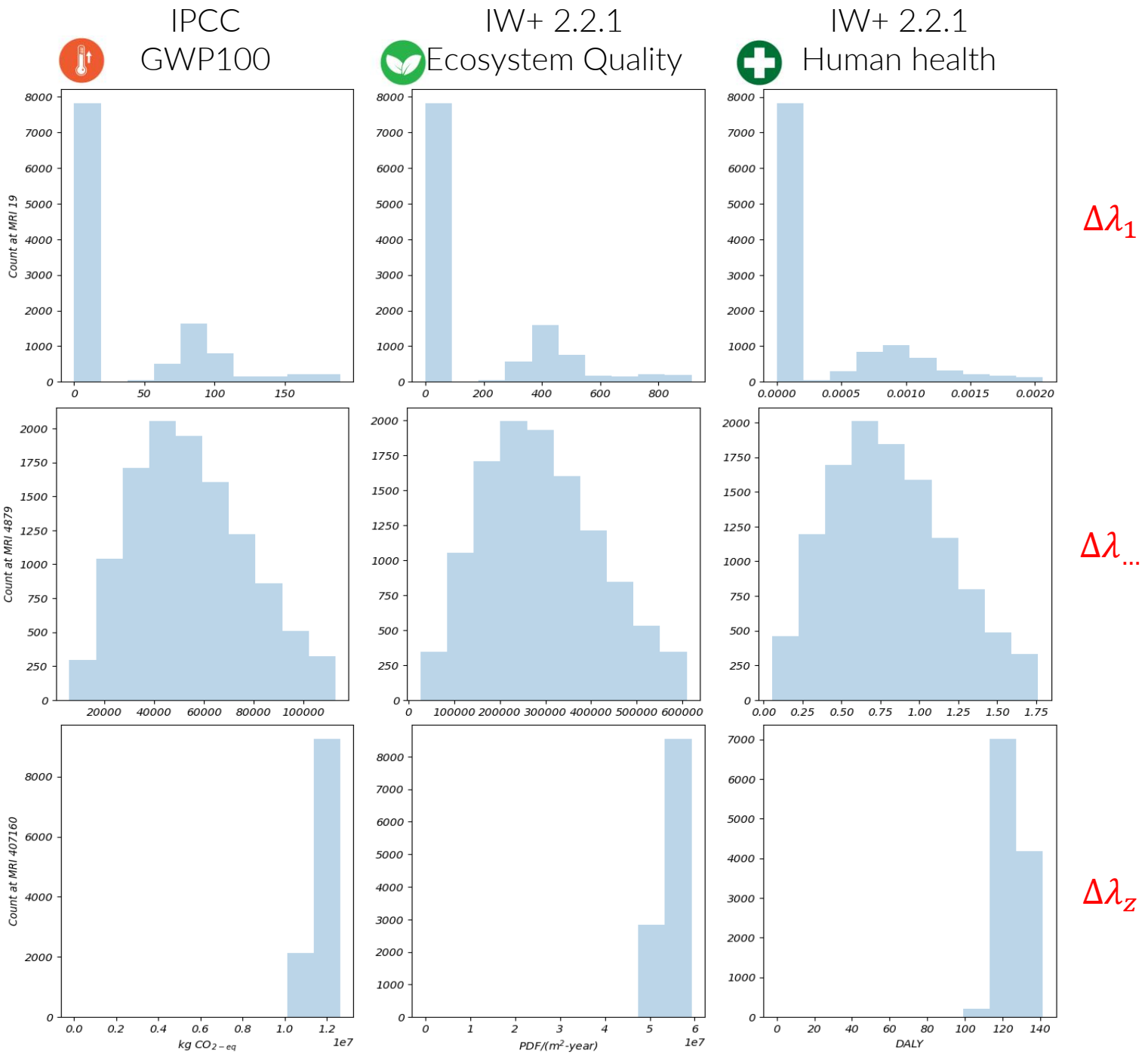
Sample outputs:



Expected losses over the service life of the structure (50 years):

$$E[\sum X] = \int_0^{\infty} \lambda(x)dx$$

16.5 tons CO_{2-eq}
78 900 PDF/(m²-year)
0.184 DALY



$\Delta\lambda_1$

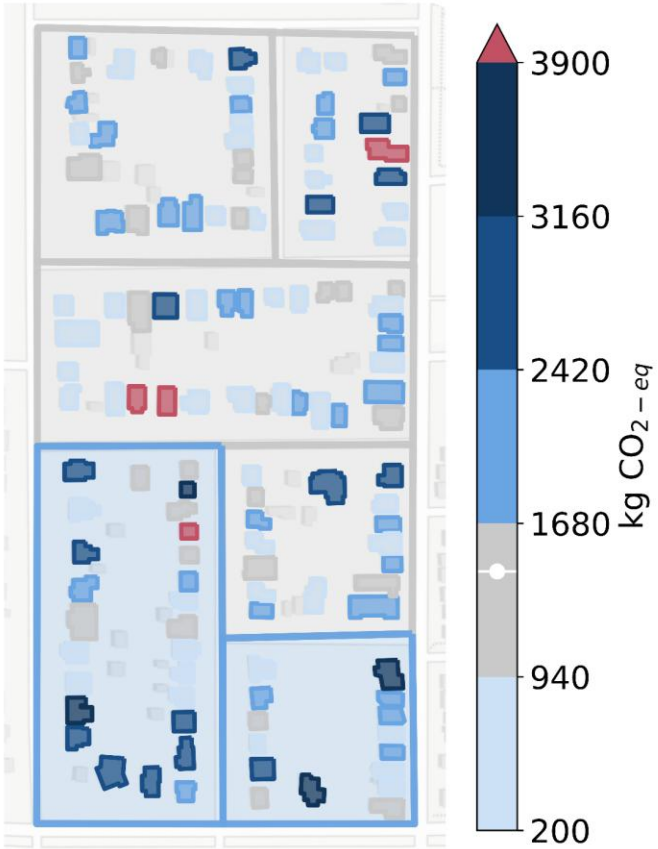
$\Delta\lambda_{...}$

$\Delta\lambda_z$

Demonstration

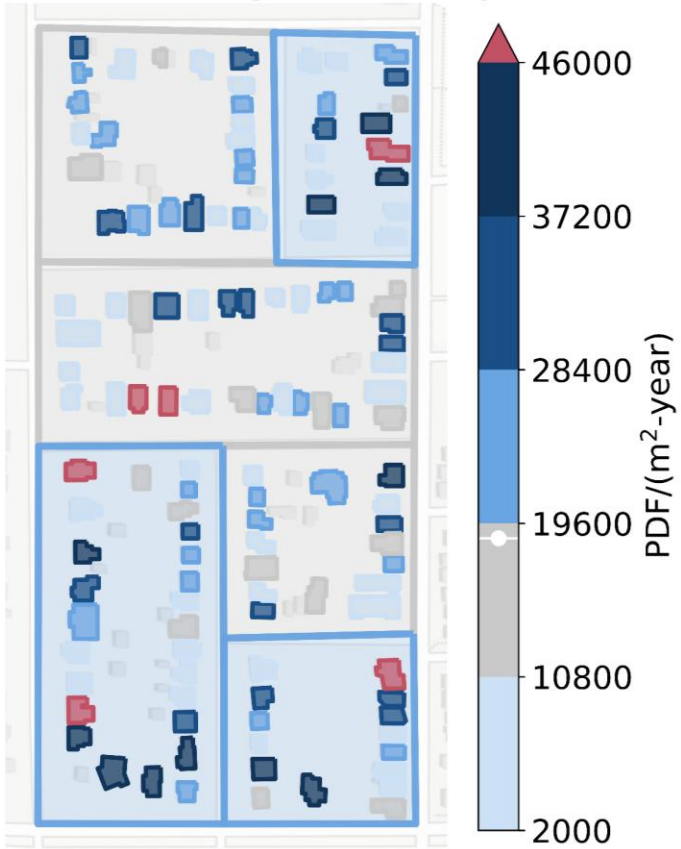
Sample outputs:

IPCC 2021 - GWP100



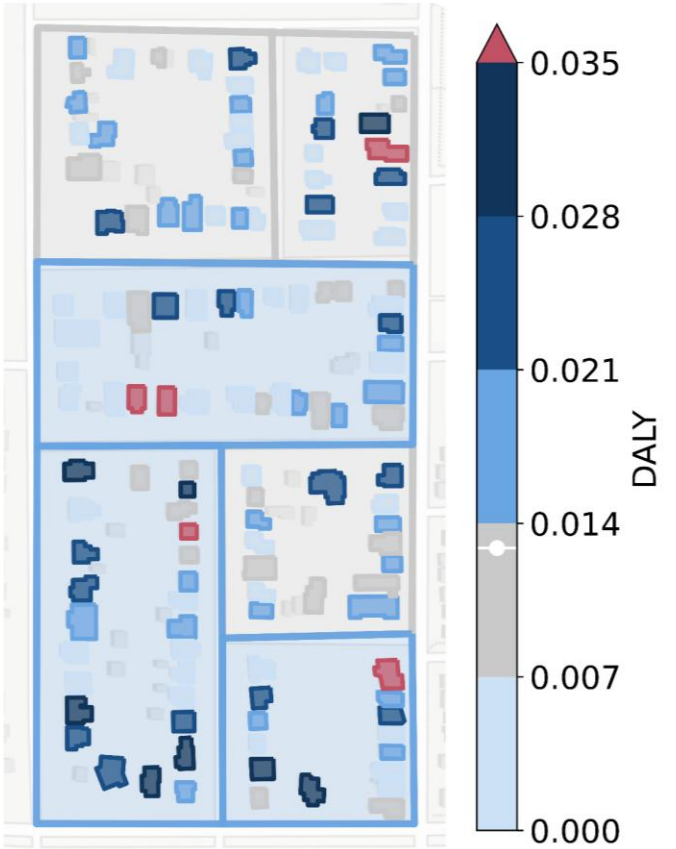
50 years: 202 tons CO_{2-eq}

IW+ (2.2.1) Ecosystem Quality



$2.64 \cdot 10^6$ PDF/(m²-year)

IW+ (2.2.1) Human Health



1.85 DALY

Outlooks

Summary:

- The coupling framework enables to explore natural hazard resilience in LCA for the built environment.
- The dual presampling format incorporates stochastic foregrounds seamlessly, reducing computational time.
- The underlying methodology preserves granularity at output level.

Future directions:

- Coupling with advanced modes of LCA (e.g., prospective LCA)
- The methodology could be applied where stochastic LCA connects in series with other upstream models.

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Github : https://github.com/xtanguay/pelicun_2_brightway2

Questions & comments

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Coupling framework

Dataset perspective

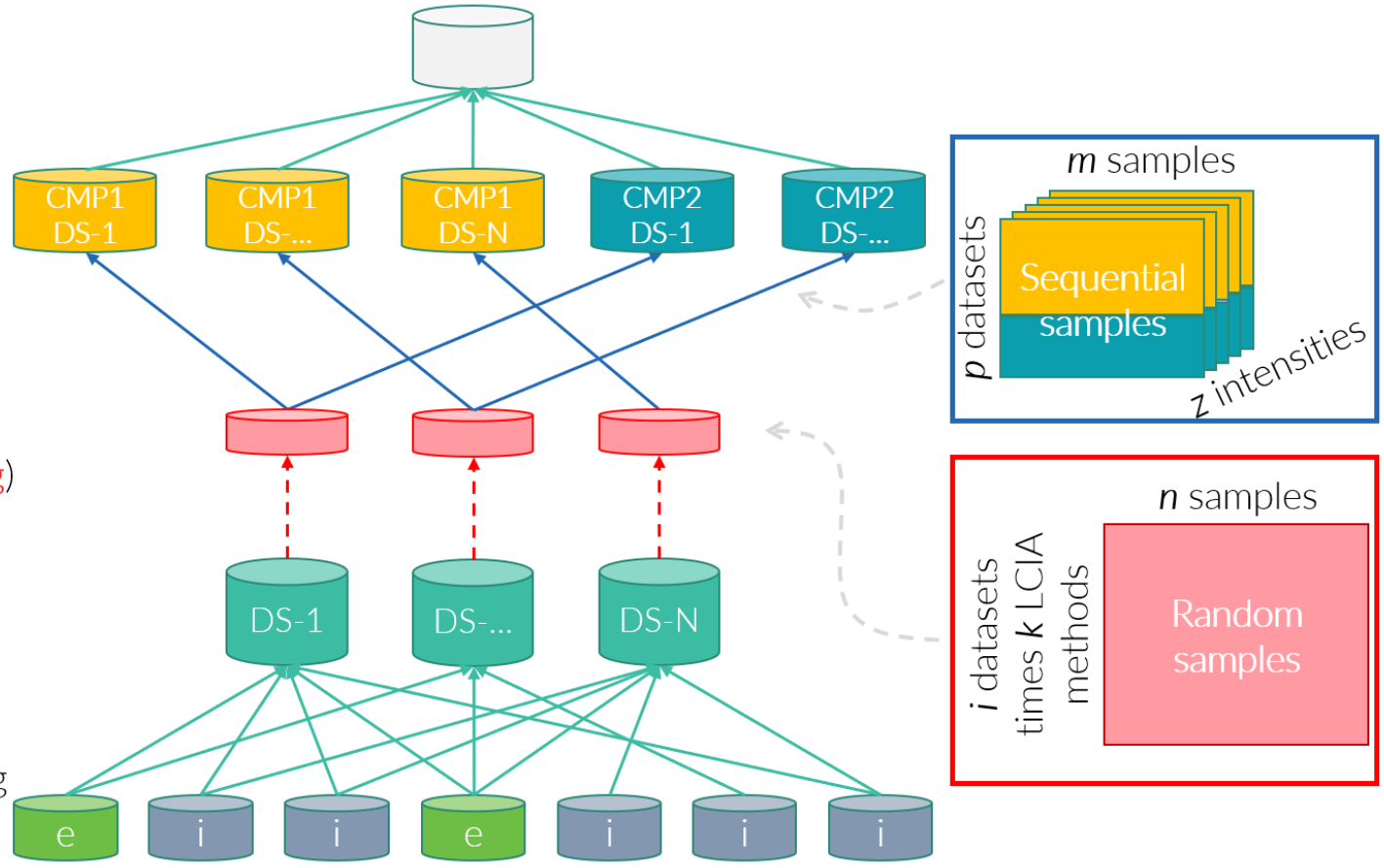
5 Reference flow creation

4 Foreground dataset creation (with sequantial presampling)

3 Aggregated dataset creation (with random presampling)

1 Generic loss dataset creation

2 Background LCI modeling (intermediate flows : i and elementary flows: e)



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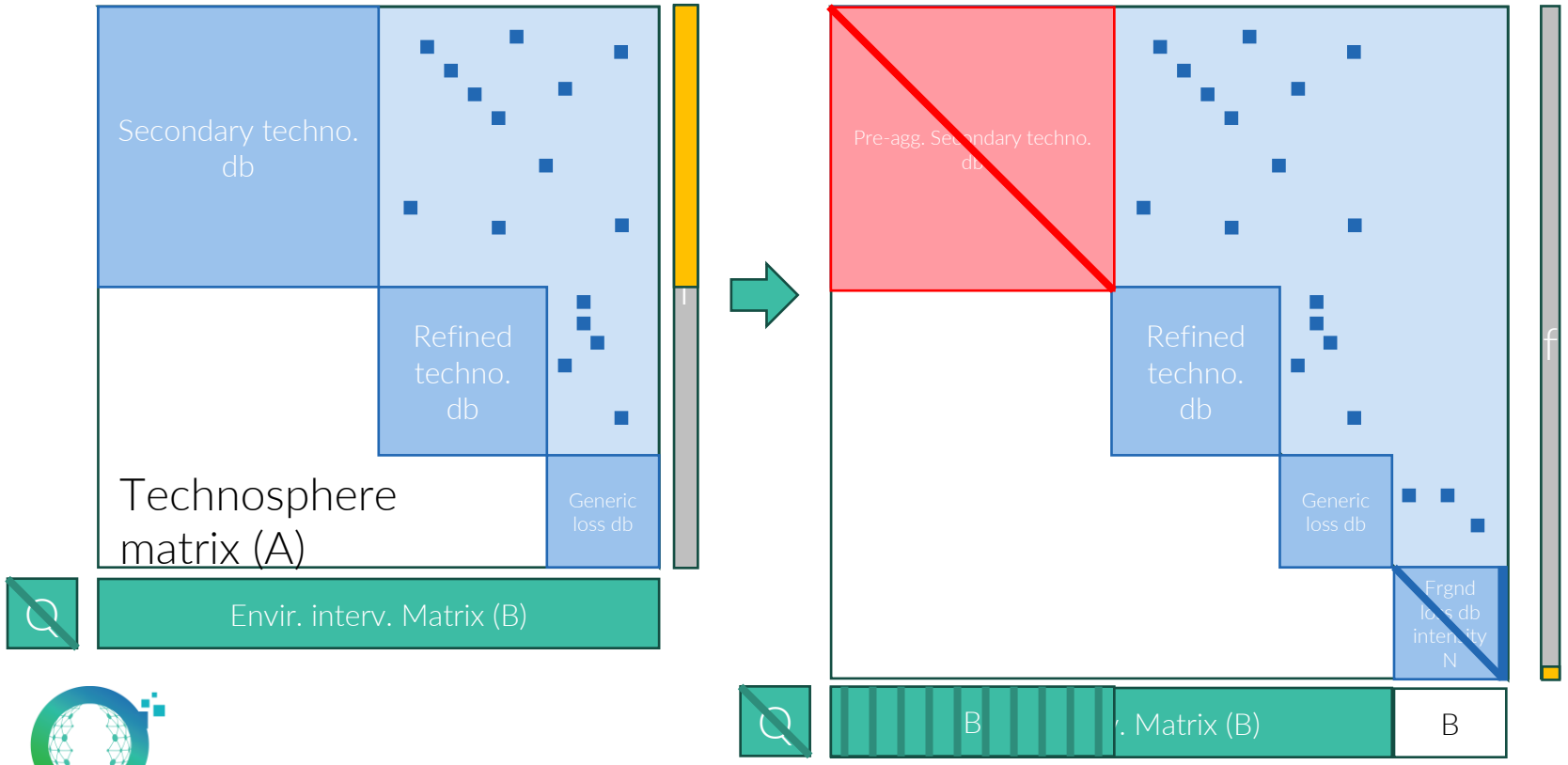
Coupling framework

Distinctions with Lesage et al. 2018:



As proposed :

i. Foreground modeling is performed prior to preaggregation

ii. The preaggregation is performed on a subset of the technosphere

iii. A direct access to first-tier contribution is provided.

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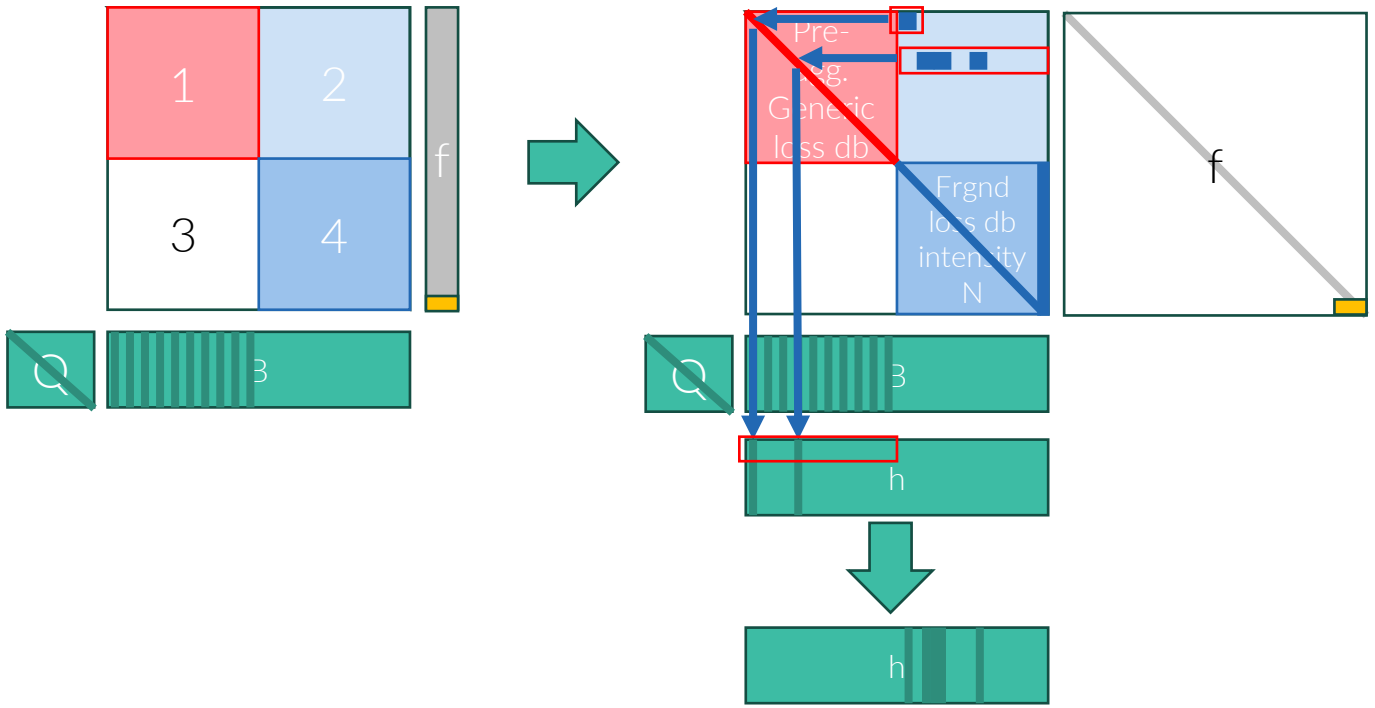
Coupling framework

First-tier contribution:



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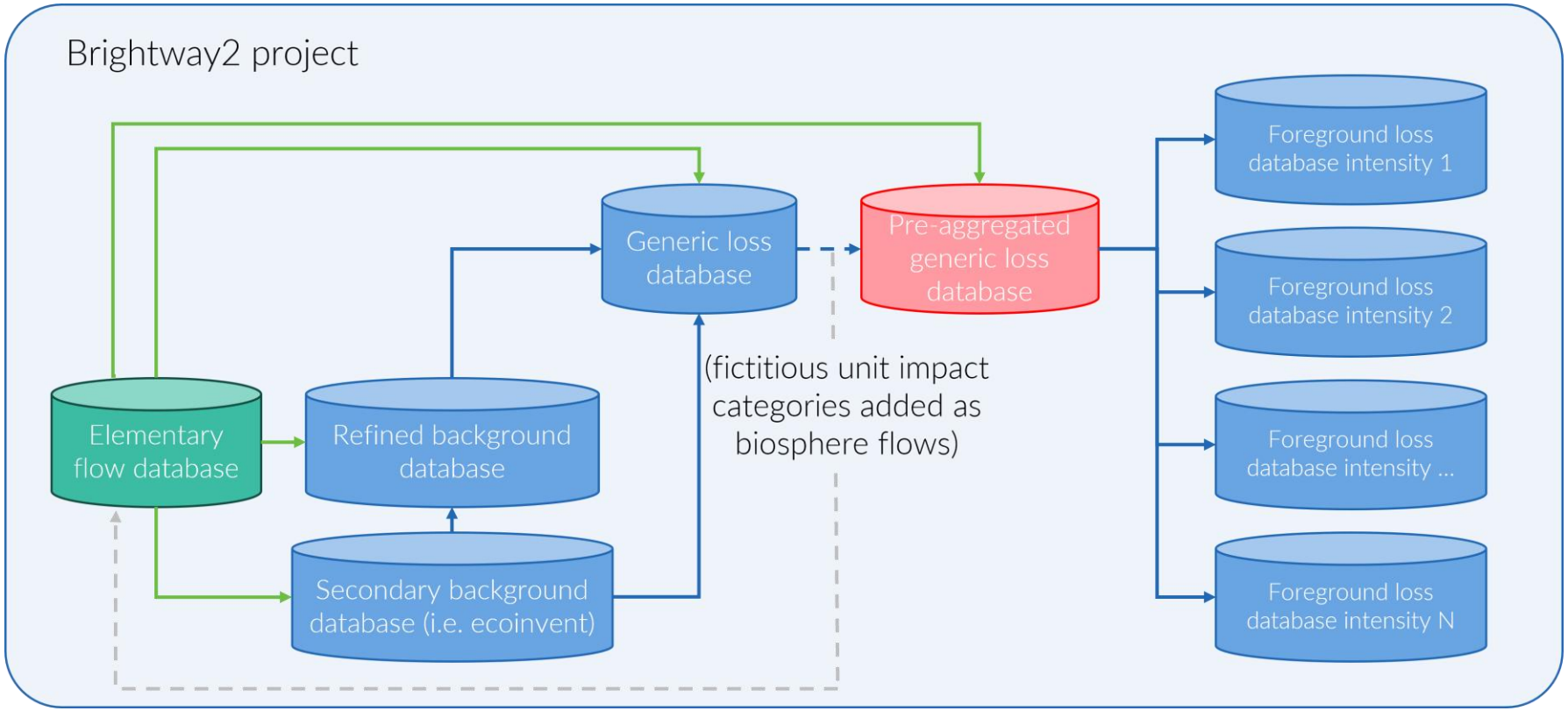
Coupling framework

Database relationship:



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(individual building)

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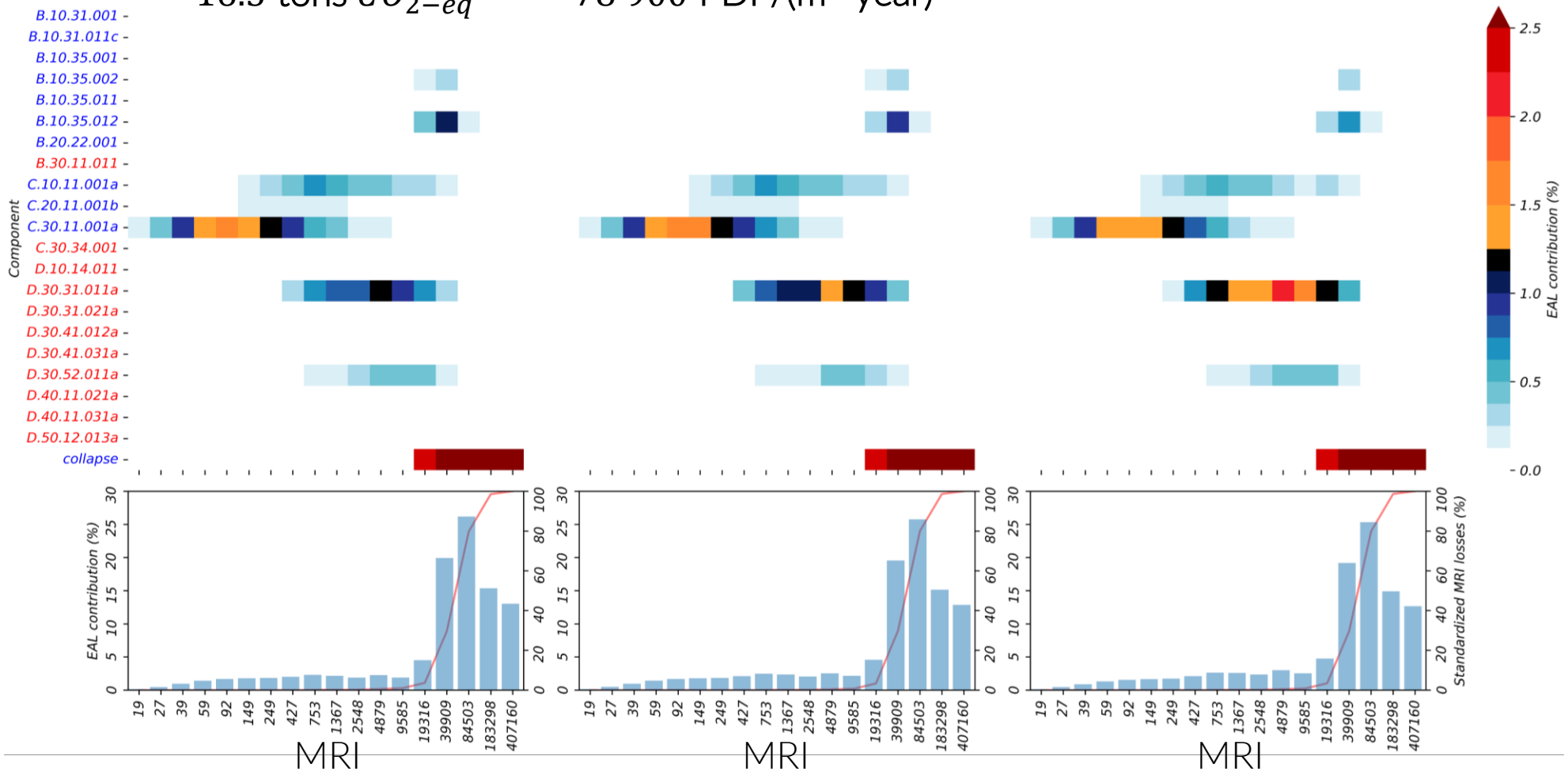
Drift sensitive component

Acceleration sensitive component



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