Mechanisms to incentivise fossil fuel divestment and implications for investors risk and return

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Research is funded by Accounting & Finance Association of Australia and New Zealand (AFAANZ), and Royal Thai Government Scholarship

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Paper available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4131449

Software Paper available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4357488

Software available on https://github.com/QuantFILab/Divfolio

Sidles and Materials available on https://github.com/QuantFILab/IME2023-Presentation

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Fossil Fuel Divestment Strategies?

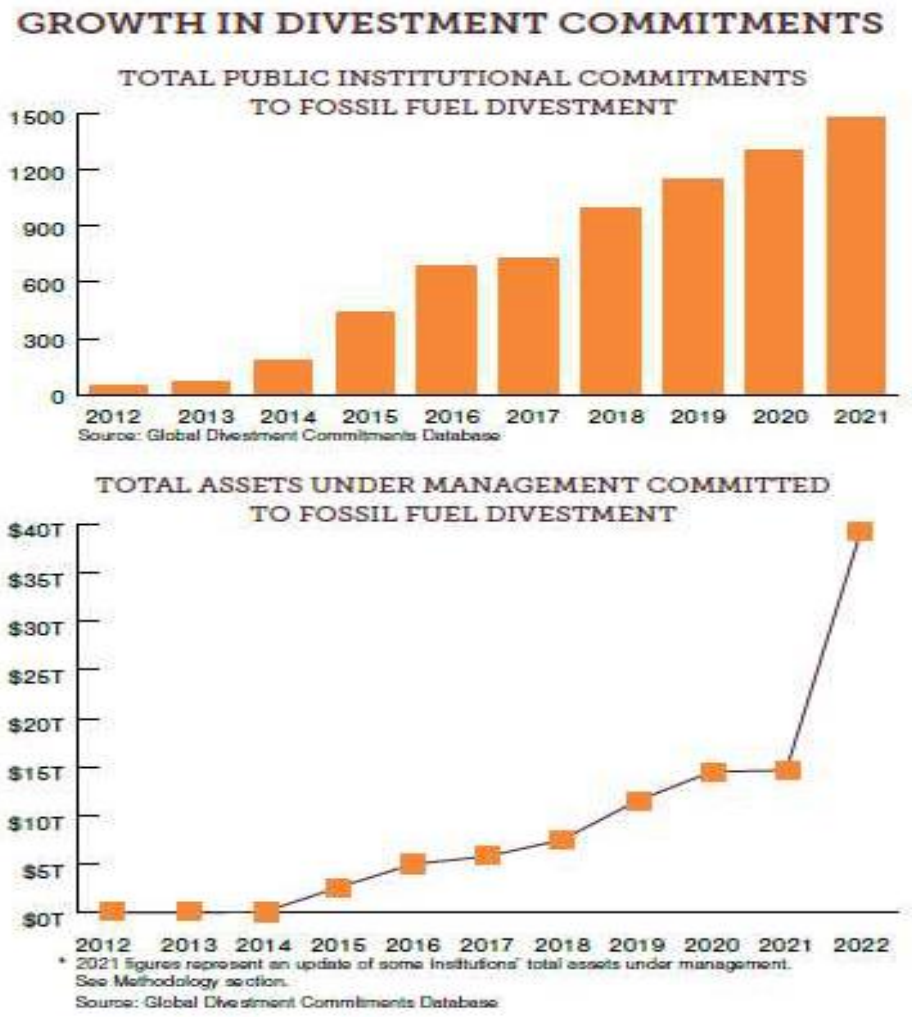
Fossil Fuel Divestment Strategies?

UN Website

Toronto350.org

- Global Environmental Challenge
- Divestment Campaigns
- Paris Agreement/COP26
- SDGs
  - Climate Action (13)
- Principal of Sustainable Finance
  - Environment

Fossil Fuel Divestment Strategies?



- **Investors total committed funds US$40.43 trillion (AUM) –**
- **Public institutions >1500**
  - Global Fossil Fuel Commitment Database (https://divestmentdatabase.org/)
- **Not only institutions and assets under management continuously increasing but accelerating.**
  - pension funds
  - Endowments
  - COP26/World Economic Forum

Open problems addressed by our case studies

- What are the effects of different rates of divestment?
- How should divested capital be optimally redeployed?
- How does divestment influence diversified versus concentrated portfolios?
- How do we quantify carbon footprint of divestment and non-divested portfolios?
- Does divestment adversely select particular demographic profiles for investors?
- Does divestment influence the robust covariance structure of portfolio

Marupanthorn, Pasin and Sklibosios Nikitopoulos, Christina and Ofosu-Hene, Eric and Peters, Gareth and Richards, Kylie-Anne, ***Mechanisms to Incentivise Fossil Fuel Divestment and Implications on Portfolio Risk and Returns*** (June 8, 2022). Available at SSRN: https://ssrn.com/abstract=4131449 or http://dx.doi.org/10.2139/ssrn.4131449

Marupanthorn, Pasin and Peters, Gareth and Ofosu-Hene, Eric and Sklibosios Nikitopoulos, Christina and Richards, Kylie-Anne and Richards, Kylie-Anne, ***DivFolio: A Shiny Application for Portfolio Divestment in Green Finance Wealth Management*** (February 14, 2023). Available at SSRN: https://ssrn.com/abstract=4357488 or http://dx.doi.org/10.2139/ssrn.4357488

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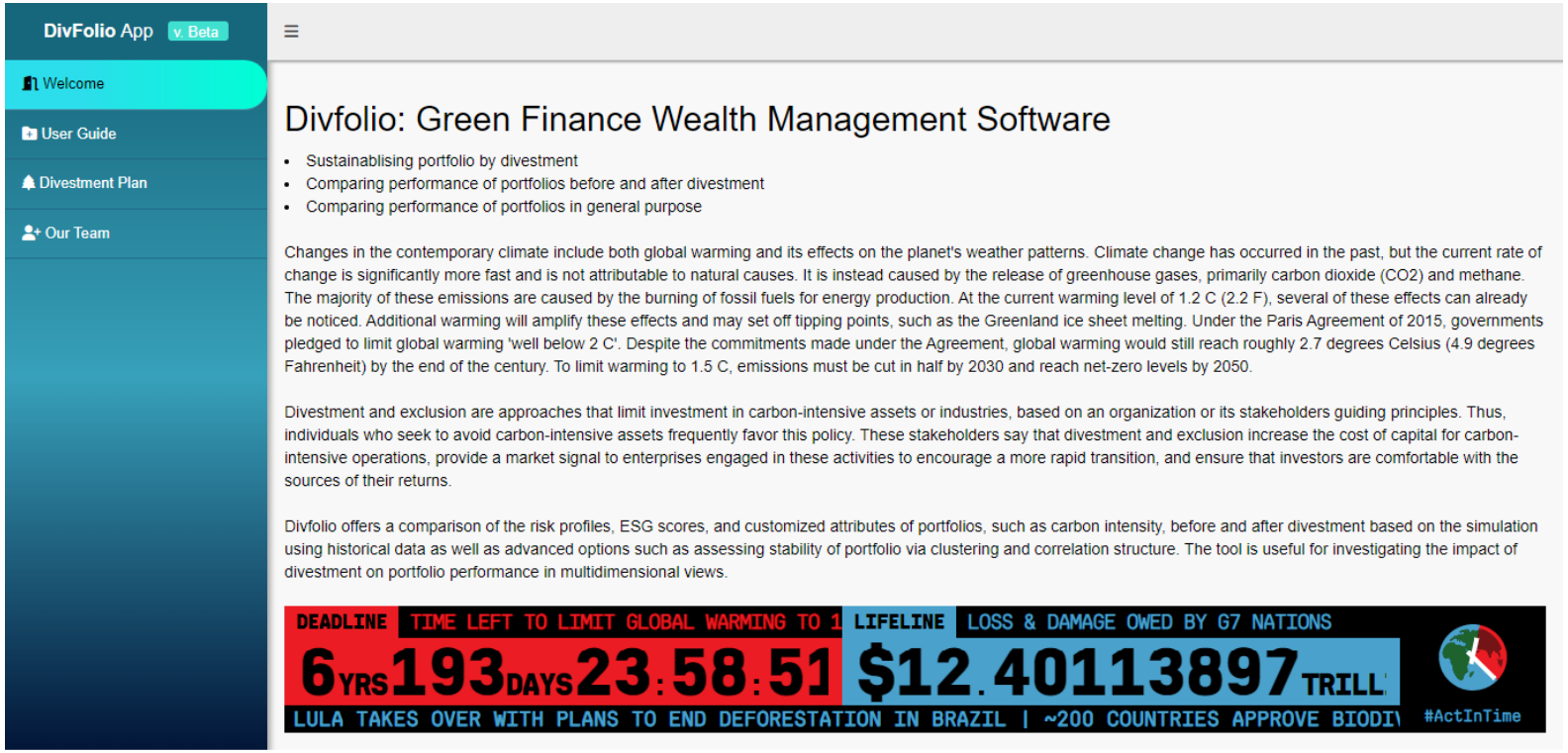


Multi-period Approach to Divestment and Reinvestment

Multi-period Portfolio Optimization Approach to Divestment

h-period optimization

$$w^* = \underset{w_{t+1}, w_{t+2}, \ldots, w_{t+h}}{\operatorname{argmax}} \quad \mathbb{E}[U(r_{t+1}w_{t+1}, r_{t+2}w_{t+2}, \ldots, r_{t+h}w_{t+h} | \mathcal{F}_t)]$$

- r_t is the return at time t
- w_t is the investment weight at time t
- I is the set of investable assets
- J is the set of divestable assets
- N_I is the number of investable assets
- N_J is the number of divestable assets
- D_t is the limit of the divestable weight
- $\mathcal{F}$ is the information filtrations at time t

$$\text{s.t.} \quad \sum_{i=1}^{N_I} w_{i,t+k} + \sum_{j=1}^{N_J} w_{j,t+k} = 1 \quad \text{Full investment}$$

$$\sum_{i=1}^{N_I} |w_{i,t+k}| + \sum_{i=1}^{N_J} |w_{j,t+k}| \leq 1.3 \quad \text{Leverage constraint}$$

$$\sum_{j=1}^{N_J} w_{j,t+k} \leq D_{t+k} \quad \text{Divestment constraint}$$

$$\text{where } k = t+1, t+2, \ldots, t+h$$

Multi-period Portfolio Optimization Approach to Divestment

Challenges

- Complicated to solve analytically in the closed form
- Computationally expensive to compute in large portfolio over many time steps
- Path-dependent optimization in both backward and forward solving
- Leverage and divestment constraints to be considered

Approximation

- Local linearising the utility function to be additive, leading to simplifying the problem to solving sequential local single portfolio optimization
- Approximating constrained optimization using rounding approximation

Approximation of Multi-period Portfolio Optimization

Objectives Function: Local linearising the utility function to be additive, leading to simplifying the problem to solving sequential local single portfolio optimization

$$
\begin{aligned}
w^* = & \underset{w_{t+1},w_{t+2},\ldots,w_{t+h}}{\operatorname{argmax}} && \mathbb{E}[U(r_{t+1}w_{t+1}, r_{t+2}w_{t+2}, \ldots, r_{t+h}w_{t+h}|\mathcal{F}_t)] \\
\approx & \underset{w_{t+1},w_{t+2},\ldots,w_{t+h}}{\operatorname{argmax}} && \mathbb{E}[U(r_{t+1}w_{t+1}) + U(r_{t+2}w_{t+2}) + \cdots + U(r_{t+h}w_{t+h})|\mathcal{F}_t)] \\
\approx & \underset{w_{t+1},w_{t+2},\ldots,w_{t+h}}{\operatorname{argmax}} && \mathbb{E}[U(r_{t+1}w_{t+1})|\mathcal{F}_t)] + \mathbb{E}[U(r_{t+2}w_{t+2})|\mathcal{F}_{t+1})] + \cdots + \mathbb{E}[U(r_{t+h}w_{t+h})|\mathcal{F}_{t+h-1})]
\end{aligned}
$$

Feasibility Refinement for Multi-period Portfolio Optimization

Constraints: for every time rebalancing of the unconstrained single-period optimization

1. Rounding leverage constraint

$$w^s_{box} = \begin{cases} 0.3 \times (w^s / \sum_{s\in S} w^s), & \sum_s w^s > 0.3, \\ w^s, & \sum_s w^s \leq 0.3, \end{cases}$$

$$w^l_{box} = \begin{cases} 1.3 \times (w^l / \sum_{l\in L} w^l), & \sum_l w^l > 1.3, \\ w^l, & \sum_l w^l \leq 1.3, \end{cases}$$

- L is the set of long position assets
- S is the set of short position assets

2. Rounding divestment constraint

$$\widetilde{w}^{l,div} = D(t) \times \frac{w^{l,div}_{box}}{\sum_{l\in L} w^{l,div}_{box}} \quad \text{or/and} \quad \widetilde{w}^{s,div} = -D(t) \times \frac{w^{s,div}_{box}}{\sum_{s\in S} w^{s,div}_{box}}.$$

Feasibility Refinement for Multi-period Portfolio Optimization

3. Rounding reinvestment constraint

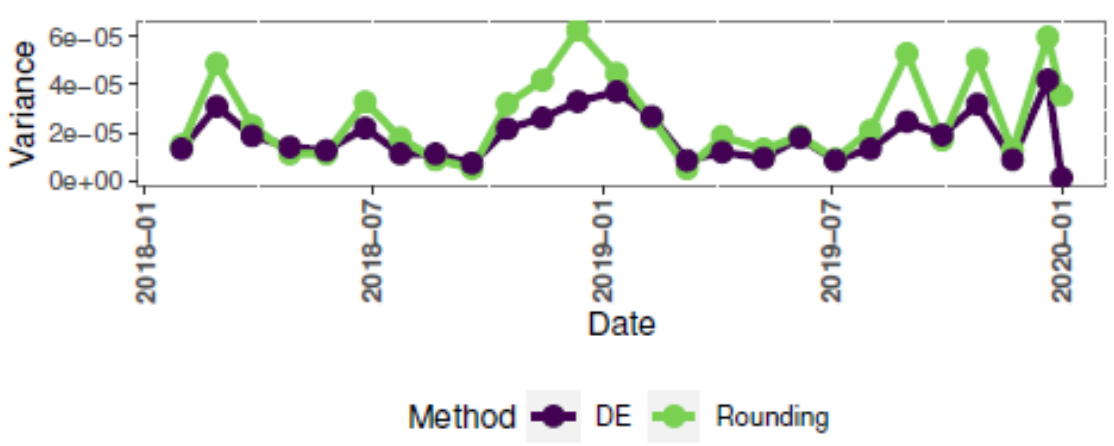
$$w_{ex} = \begin{cases} \sum_{l \in L} \widetilde{w}_{box}^{l,div} - D(t), & \text{if } \sum_{l \in L} w_{box}^{l,d} \geq D(t) \\ \sum_{s \in S} w_{box}^{s,div} + D(t), & \text{if } \sum_{s \in S} w_{box}^{s,div} \leq -D(t) \\ \sum_{l \in L} w_{box}^{l,div} + \sum_{s \in S} w_{box}^{s,div}, & \text{if } \sum_{l \in L} w_{box}^{l,div} \geq D(t) \text{ and } \sum_{s \in S} w_{box}^{s,div} \leq -D(t) \\ 0, & \text{otherwise.} \end{cases}$$

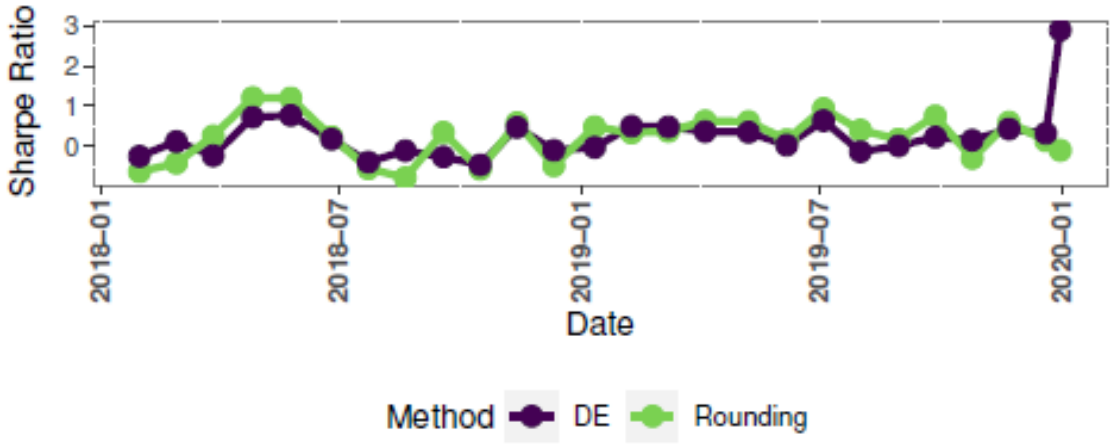
$$\widetilde{w}^{inv} = w^{inv} + \frac{w^{inv}}{\sum_{l \in L} w^{inv}} \times w_{ex}.$$

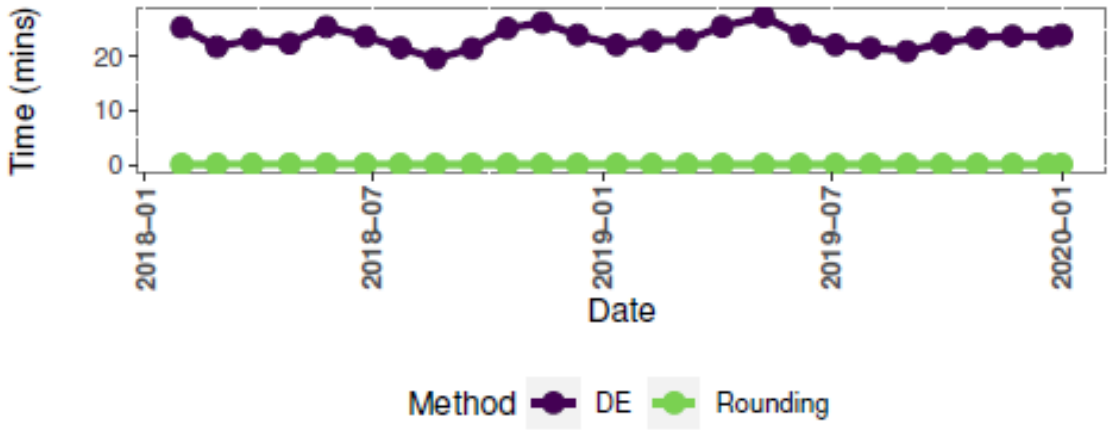
It is not difficult to verify that $\widetilde{w}^{l,div} 1 + \widetilde{w}^{s,div} 1 + \widetilde{w}^{inv} 1 = 1$.

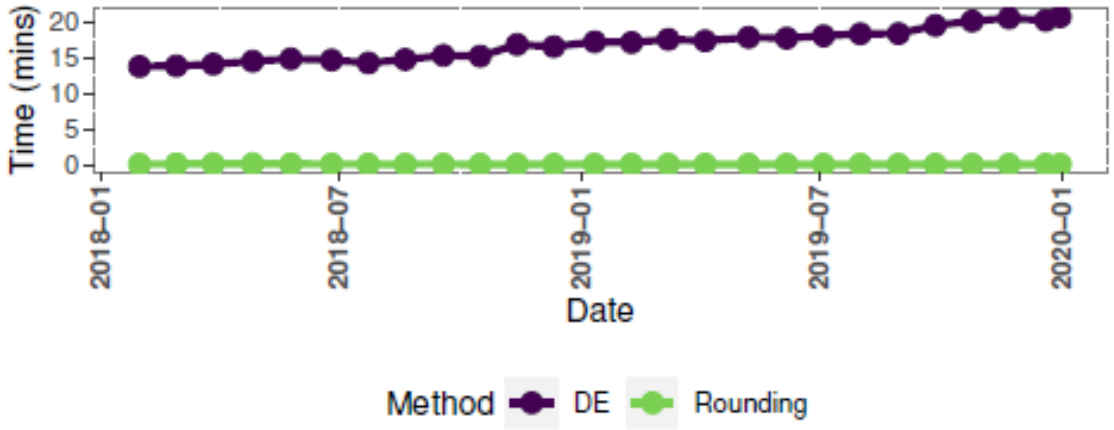
Approximation of Multi-period Portfolio Optimization

Rounding approximation compares to Differential Evolution – Very closed in risk profiles

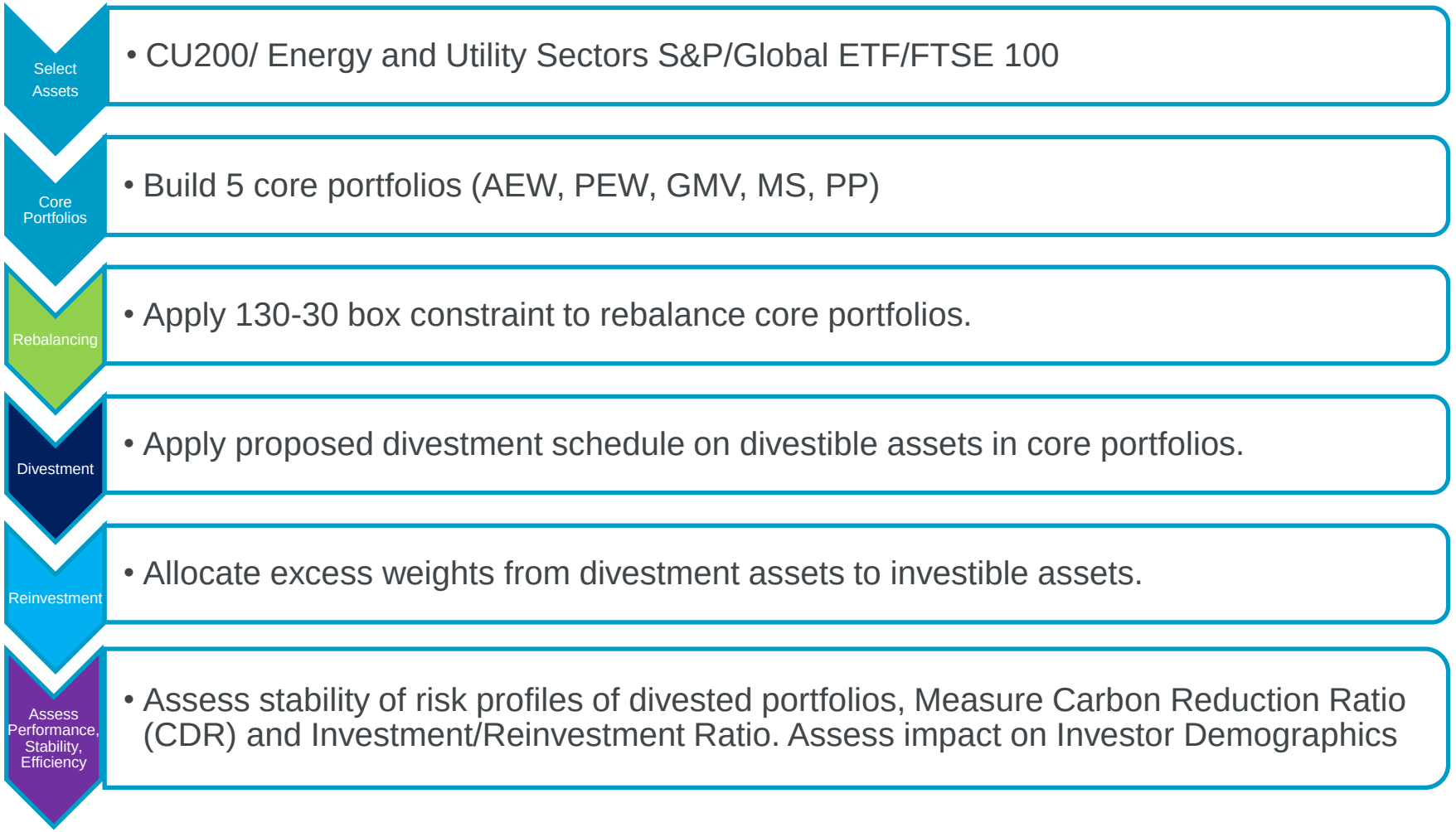








Divestment and reinvestment framework



Experimental Design

- S&P 500, with the divested funds (CU200, energy and utilities) reinvested in other sectors.

We study the impact and stability on the portfolio's risk and return behaviour by divesting from fossil-fuel intensive sectors and reinvesting this capital in other sectors as well as allowing divestment by using leveraged positions.

- ETFs, with the divested carbon intensive assets

We study the impact on key investors demographics: management fees, ESG score and carbon footprint change, and the dividend yields attributed to divestment practices.

- FTSE 100, with the divested high ESG risk

We study the impact on portfolio diversification and robust covariance structure.

DivFolio: A Shiny Application for Portfolio Divestment in Green Finance Wealth Management

Guideline of using divestment software

- Full guideline available on https://github.com/QuantFILab/Divfolio
- Example CSV Files available on https://github.com/QuantFILab/IME2023-Presentation
- Web application available on https://quantfilab.shinyapps.io/divfolioserveri/