# Review of assumptions used to model the financial situation of the Colorado Public Employees' Retirement Association (PERA)

## FINAL REPORT

July 2024

FINAL DRAFT FOR COMMENTS

# Executive summary

Following our review, we consider that due to shortcomings in financial and non-financial assumptions, the fund's sensitivity to investment performance, and the significant likelihood of not achieving sufficient returns with acceptable risk, PERA does not appear to be on track to achieving full funding by 2048. There is also a material risk of the fund reaching a point of no return, being a funded status of less than 50%. Actions could be taken, at some cost, to improve PERA's position.

## Position of the fund and actuarial and financial assumptions

- Our modeling indicates an expected portfolio return of 6.71%, materially below the current return assumption of 7.25%.
- The funding path presents material risks of reaching points of no return and fund insolvency (a funded ratio of less than 50%).
- The need for a higher-risk approach is driven by the need for a high rate of return given PERA's low funding status. This is exacerbated by PERA's negative cash flow position which makes the funding path particularly sensitive to portfolio performance.
- The fund's current financial modeling and risk measurement approach has important shortcomings that reduce the reliability of its projections, including in relation to asset and macro factor correlations and the recognition of return and risk asymmetry.
- The fund exhibits consistent annual actuarial losses of approximately 1%. This appears to relate to the partial (rather than full) application by Segal Group of the recommendations of the 2021 GRS report. Those recommendations were aimed at addressing the shortcomings in the assumptions of PERA's previous actuary and were only partly implemented.
- As a consequence, there is a material likelihood that PERA's reported actuarial accrued liability has been materially understated. Actuarial accrued liability may be 10% higher than reported.

## Options for improving the funded ratio

- Various options are available to improve the funded ratio path. These include adjustment of the portfolio's positioning within the existing bands (or widening those bands); making a lump-sum contribution to the plan; or slightly increasing non-State contributions.
- These approaches can reduce the risk of reaching points of no return (less than 50% funded), to between 15% and 16% from the current 18%.
- A more innovative risk management option would be the creation of a Colorado wealth fund as a parallel and separate fund to contribute to covering shortfalls if PERA is underfunded in 2048. By decoupling it from a pension plan's liability constraints, such a fund could follow a

distinct value-creation strategy that would be likely to materially outperform the PERA portfolio.

- A $2bn fund created in 2024 could grow to approximately $21 billion by 2048 to cover funding shortfalls at PERA, and could cover a material proportion of projected PERA shortfalls even in low growth scenarios, while providing beneficial externalities to Colorado. On an aggregate basis it could reduce the horizon to full funding to 2043.

# Introduction

We have been mandated to evaluate the economic and non-economic assumptions underpinning the projections of PERA's funded ratio. The mandate requires an examination of the validity of a range of assumptions, with a view to assessing whether PERA is on track to achieve 100% funding by 2048. We previously set out our preliminary findings in an interim report delivered in May 2024 to the Colorado Legislative Council.

That report indicated that although on a narrow view PERA's could be considered on track to achieve the funding target, this position is not supported when considered in broader context. The wide dispersion of likely investment returns, coupled with the plan's sensitivity to small variations in investment performance and the lower mean expected returns forecasted by our modeling (which simulates return distributions and correlations with greater realism than Segal modeling), combine to present a picture that implies significant risks to the funding target. This final report confirms and elaborates on that conclusion, including a review of non-economic assumptions, which present material shortcomings.

## Policy context

We understand that the broader policy context of these assessments is to assist the Pension Review Subcommittee of Colorado's Legislative Council to determine whether any policy action may be appropriate or desirable to ensure that PERA meets the desired funding target.

Accordingly, in addition to providing an assessment of the actuarial assumptions underpinning the Segal Group report, our report considers potential options for improving PERA's position and outlook. Those options include no-cost adjustments to PERA's allocation within its allocation bands, a $2 billion lump sum contribution by the state, a 1% increase in non-state contributions, and the creation of a standalone $2 billion state-level wealth fund to cover 2048 funding shortfalls. Of these options, the wealth fund has the biggest impact for PERA, while also presenting favorable externalities for Colorado if implemented.

## Structure of this report

The report is structured as follows:

**Part A** sets out the characteristics of PERA and overall outlook.

**Part B** evaluates the non-economic assumptions underpinning PERA's projected cash flows.

**Part C** evaluates PERA's economic assumptions.

**Part D** assesses the portfolio's risk profile and the likely timing for achieving full funding in that context.

**Part E** proposes and evaluates options for improving PERA's position and prospects for achieving the funded ratio target.

**Part F** sets out our recommendations to the Pension Review Subcommittee.

## Information and data

This report draws on the following information sources:

- Segal Group's Signal Light Reporting for the Hybrid DB Plan, July 13, 2023
- Segal Group's Actuarial Valuation and Review of PERA funds as of December 31, 2022, dated 6 June 2023
- Segal Group's 2020 Actuarial Experience Report presenting an Analysis of Actuarial Experience during the period January 1, 2016 through December 31, 2019
- PERA's Annual Comprehensive Financial Report for year ended December 31, 2023
- PERA's Annual Comprehensive Financial Report for year ended December 31, 2022
- GRS report to the Legislative Council Staff Pension Review Commission, September 21, 2021
- 2023 PERA Salary and Pension Benefit Cash Flows

# Part A
# Overview: Fund characteristics and outlook

## Current position

Based on the Annual Comprehensive Financial Report for year ended December 31, 2023, PERA's unfunded liability at that time stood at $27.5 billion, with a funding level of 69.6%. For comparison purposes, some data in this section utilize 2022 figures, as more than half of the US pension fund information for the current year is not yet available. As of December 31, 2022, PERA's unfunded liability at that time stood at $26.3 billion, with a funding level of 69.9%.

## Fund maturity

PERA is a comparatively mature fund, in the sense that on several metrics, its obligations are skewed toward its retired beneficiaries rather than its active ones. The consequence of this is that the fund is more sensitive to changes in investment returns as a source of income than to changes in contribution levels. This is an important consideration for decision makers when considering measures to ensure the fund's sustainability (options for such measures are set out in Part C below).

## PVFB Retiree to Total PVFB

The percentage of the Present Value of Future Benefits (PVFB) belonging to retirees and survivors is 55%. This means that out of the total PVFB of the pension plan, 55% is attributable to retirees and survivors who are currently receiving benefits. A comparison with 228 U.S. public pension funds shows that PERA is slightly above the median (53%) in this respect. Figure 1 shows the distribution of retiree PVFB for 228 US pension funds together with the positions of PERA and its five divisions.

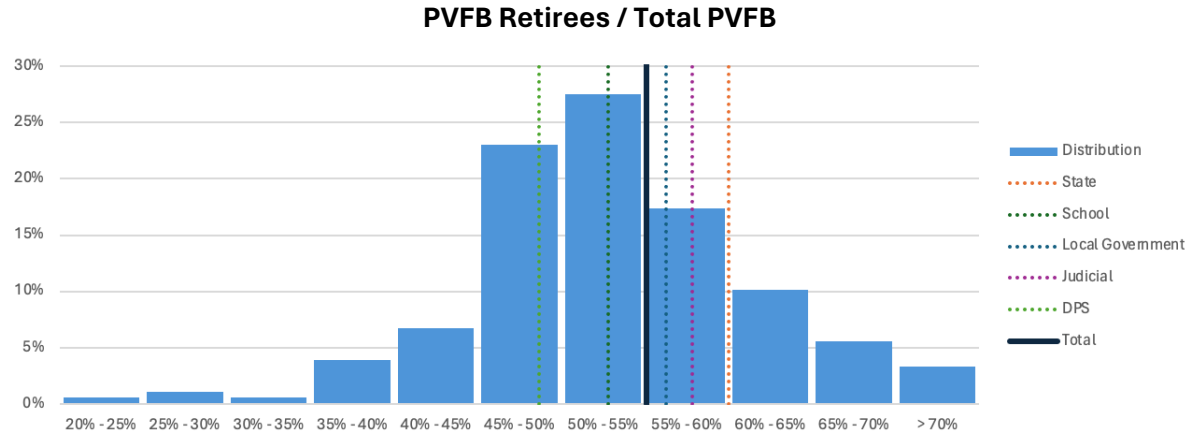



*Figure 1*

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

| | PVFB Retirees as % of Total, 2022 |
|---|---|
| State | 60% |
| School | 53% |
| Local Government | 56% |
| Judicial | 58% |
| DPS | 49% |
| **PERA Total** | **55%** |
| Median Public Pension | 53% |

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

## UAAL to payroll ratio

Another ratio to monitor is the Unfunded Actuarial Accrued Liability (UAAL) to payroll. A higher ratio suggests a larger burden on the payroll to cover the pension shortfall, while a lower ratio indicates a more manageable level of unfunded liability. PERA has a higher-than-median unfunded liability to payroll ratio, with a ratio of 2.51 compared to a median of 1.93. As a consequence, the plan's funded ratio has a relatively low sensitivity to increases the contribution rate.

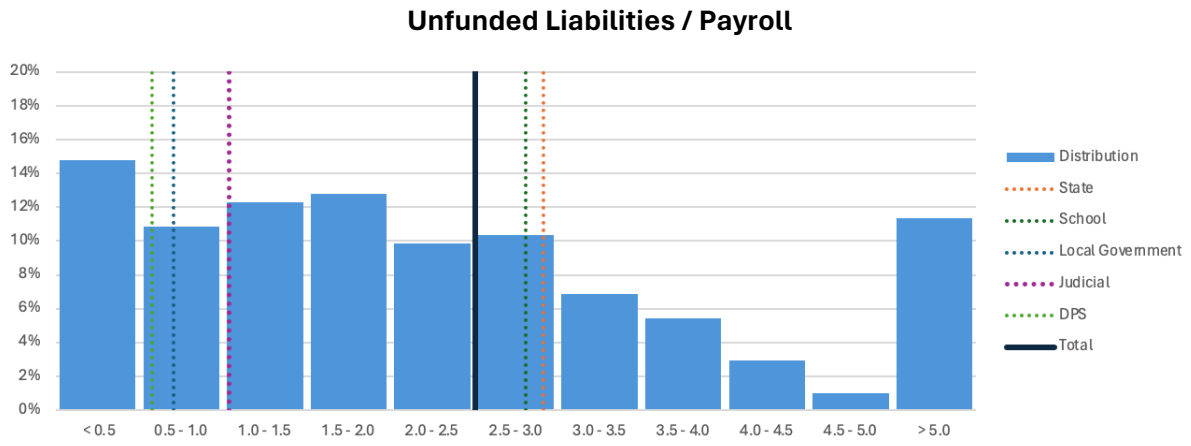



*Figure 2*

| | Liabilities to Payroll, 2022 |
|---|---|
| State | 2.91 |
| School | 2.81 |
| Local Government | 0.70 |
| Judicial | 1.04 |
| DPS | 0.57 |
| **PERA Total** | **2.51** |
| Median Public Pension | 1.93 |

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

## Negative net cash flow

The fund is cash flow negative. This makes the funded ratio evolution more acutely sensitive to fluctuations in portfolio performance, as performance must be higher to compensate for net outflows just to maintain a neutral fund position each year.

In 2022, PERA's net cash flow was -2.45% of the Actuarial Value of Assets (AVA). This means that if the investment return is less than 2.45%, it becomes necessary to draw down the fund's asset

base to cover the negative cash flow. In turn, this means that periods of underperformance need to be compensated by outperformance that not only restores average returns to the required level, but additionally rebuilds the asset base such that the target level of returns will achieve the funding target.

Figure 3 sets out a forecast of PERA's net cash flow. The chart uses cash flows received from PERA. The forecasted cash flows assumes that the employer (including Amortization Equalization Disbursement AED and Supplemental Amortization Equalization Disbursement SAED) and member contribution rates will remain the same as in 2023, together with a direct distribution of $225 million continuing into the future. The forecasted cash flows do not include the effect of the AAP, as the AAP adjustment is based on the AAP ratio and not directly on funded ratio. These assumptions will also be used for subsequent analysis.

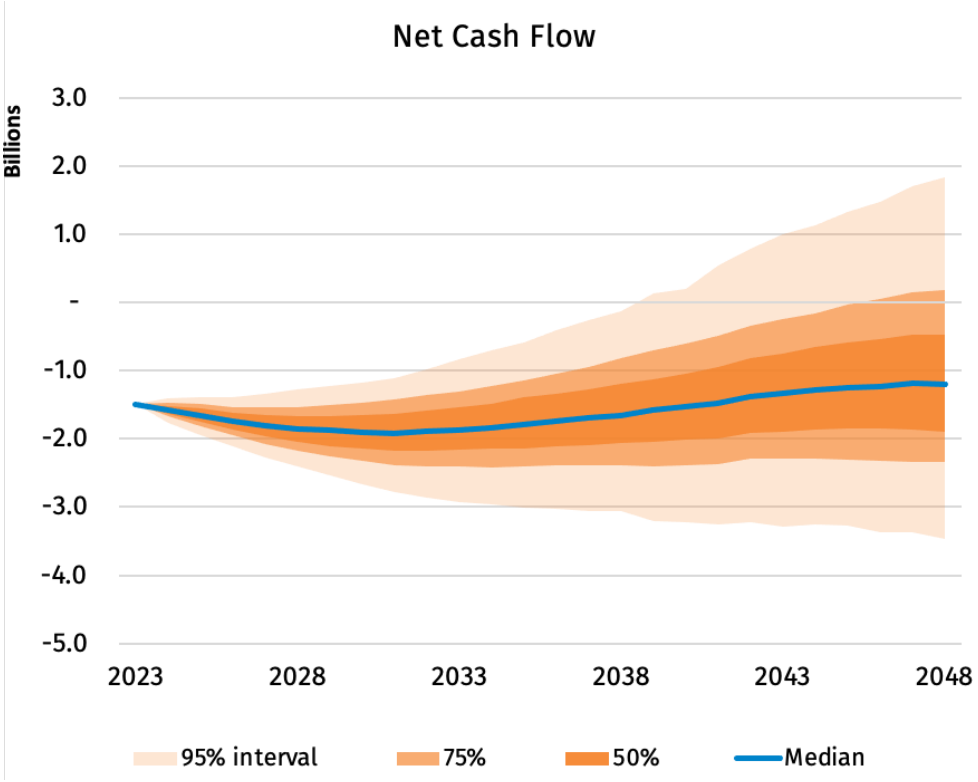



*Figure 3*

Source: PNYX, Annual Comprehensive Financial Report for year ended December 31, 2023, 2023 PERA cash flows

For context, a comparison with 228 U.S. public pension funds shows that PERA's net cash flow (-2.45%) is below the median (-2.25%). Figure 4 sets out the cash flow position of PERA together with its 5 divisions.

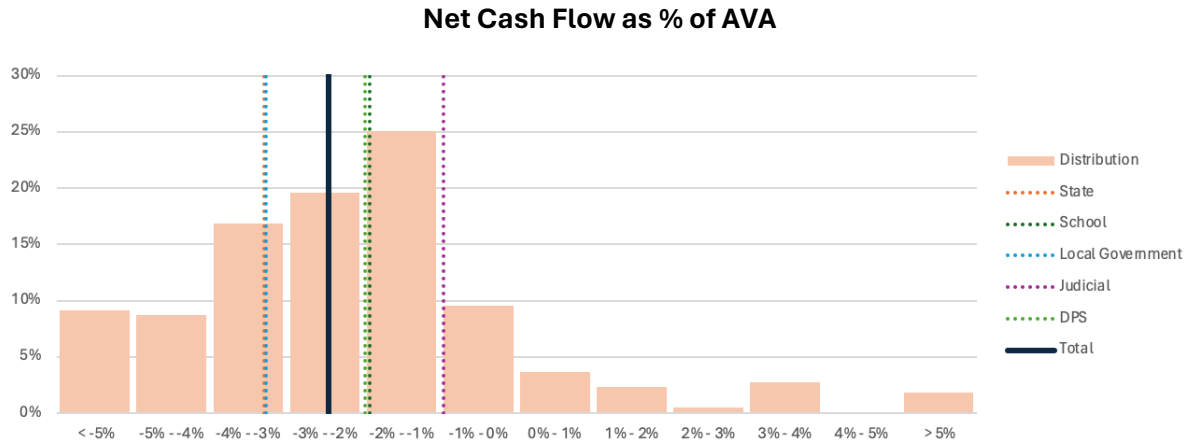



*Figure 4*

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

| | Net Cash Flow as % AVA, 2022 |
|---|---|
| State | -3.30% |
| School | -1.91% |
| Local Government | -3.26% |
| Judicial | -0.95% |
| DPS | -1.97% |
| **PERA Total** | **-2.45%** |
| Median Public Pension | -2.25% |

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

For background, a more general analysis of the effect of the net cash flow position on a plan in either over or underfunded conditions is set out in the Annex.

# Part B
# Non-economic actuarial assumptions

This Part sets out findings from a high-level review of the recent actuarial gains and losses from demographic assumptions reported in recent actuarial valuations of PERA's five defined benefit pension plans (the Plans).

We have reviewed the following documents:

- The actuarial valuation reports prepared by The Segal Group as of December 31, 2023, December 31, 2022 and December 31, 2021. We were also provided the actuarial reports as of December 31, 2020 and December 31, 2019. However, since the demographic assumptions were updated for the December 31, 2020 actuarial valuation, the gains and losses from periods prior to December 31, 2020 would not be dispositive for quantifying the extent to which the assumptions currently used to determine the Plans' liabilities understate or overstate those liabilities.
- An Actuarial Experience Report prepared by the Segal Group in 2020 that presented an Analysis of Actuarial Experience during the Period January 1, 2016 through December 31, 2019.
- An Evaluation of the economic, non-economic, and investment assumptions used to model PERA's financial situation, as required by Senate Bill 18-200, prepared by Gabriel, Roeder, Smith & Company ("GRS"), dated September 1, 2021 and addressed to the Legislative Council Staff Pension Review Commission, State of Colorado.
- We also had access to the Annual Comprehensive Financial Report of the Colorado PERA for the years ended December 31, 2023, December 31, 2022, December 31, 2021, December 31, 2020 and December 31, 2019.

## Actuarial experience review

The Segal Group prepared an Actuarial Experience Report in 2020 that presented an Analysis of Actuarial Experience during the Period January 1, 2016 through December 31, 2019

It appears that the Actuarial Experience Report is prepared every four years and is the basis for updating actuarial assumptions. According to the GRS report, the 2016 actuarial experience report had been prepared by Cavanaugh MacDonald, the actuarial firm that preceded Segal Group as the Plans' actuaries. GRS noted a number of methodological issues with the analysis prepared by Cavanaugh MacDonald, which led to the selection of demographic assumptions that were used in the actuarial valuations as of December 31, 2016 through December 31, 2019, and which, in the opinion of GRS, resulted in understatement of plan liabilities. This led to actuarial losses that were identified in each of the four succeeding years' subsequent actuarial valuation reports.

GRS noted that the Actuarial Experience Report prepared by Segal Group corrected the methodology shortcomings of Cavanaugh MacDonald. However, in selecting many of the assumptions to be used in the actuarial valuations, starting with the December 31, 2020 actuarial valuation, Segal Group only reflected a portion (often less than half) of the difference between actual plan experience and the previous Cavanaugh MacDonald assumptions. Thus, while the

demographic assumptions selected by Segal Group would likely be closer to expected experience under the plan and would produce more realistic projections of the Plans' liabilities, the results of the valuations would reasonably be expected to continue to produce actuarial losses from demographic experience. GRS recommended that the 2024 scheduled quadrennial Actuarial Experience Report be accelerated to 2022.

It appears that GRS' recommendation to accelerate the preparation of the Actuarial Experience Report was not adopted. Furthermore, there is no reference to the GRS report in the Annual Comprehensive Financial Report of the Colorado PERA for the years ended December 31, 2023, December 31, 2022, or December 31, 2021. (cf., pages 161, 165, 161, from the respective reports).

Table 1 is a summary of the actuarial gains and losses from demographic experience for the three years 2021, 2022 and 2023, with positive numbers representing increases in plan liabilities (i.e., actuarial losses) and negative numbers representing decreases in plan liabilities (i.e., actuarial gains):

*Table 1*

| | 2021 | 2022 | 2023 | Total |
|---|---|---|---|---|
| Retirement | 44,941,993 | 56,629,358 | -1,333,887 | 100,237,464 |
| Death (Mortality) | -159,446,001 | -9,150,589 | -128,973,759 | -297,570,349 |
| Withdrawal (employee turnover) | 114,149,414 | -74,234,564 | 39,316,685 | 79,231,535 |
| Pay increases (salary scale) | 207,199,081 | 454,442,094 | 791,850,222 | 1,453,491,397 |
| New Entrant | 266,145,598 | 400,029,814 | 362,064,395 | 1,028,239,807 |
| Disability | 6,521,900 | 5,577,002 | 1,736,425 | 13,835,327 |
| Other | 48,145,031 | 194,041,895 | 115,283,145 | 357,470,071 |
| Total | 527,657,016 | 1,027,335,010 | 1,179,943,226 | 2,734,935,252 |

Offsetting these losses was a gain from actual contributions to the Plans exceeding expected contributions by $216,587,126, $410,552,111 and $162,667,545 during the three years, respectively, or a total of $789,806,782. Thus, the net losses to the Plans over the three-year period was about $1.95 billion. However, if the focus is on the magnitude of the Plans' liabilities, the $2.73 billion recognized shortfall over the three-year period should be the focus.

The total actuarial accrued liability reported by the actuary with respect to the five Plans as of December 31, 2023 was $90.5 billion. Thus, the understatement of liabilities that was recognized during just the three years 2021, 2022 and 2023 represented 3% of the Plans' actuarial accrued liability.

## The 2021-2023 experience and the future

Question: Is the experience of 2021-2023 indicative of future experience?

## COVID impact

The mortality gains (i.e., higher than expected numbers of deaths) occurred during the COVID-19 pandemic. There are two schools of thought regarding what we can expect in the future.

One possibility is that the pandemic accelerated the mortality of a less healthy and more vulnerable portion of the population, being individuals who might otherwise have died soon. As a result, the population now has a higher proportion of healthier or stronger individuals and we should expect a below average number of deaths in the next few years, resulting in actuarial losses for a few years.

The alternative is that long COVID has weakened the surviving population and we will experience continued elevated numbers of deaths, resulting in continued actuarial gains for a number of years.

No one knows the answer. Only time will tell.

## Losses from pay increases in excess of expectations

Were some of these losses the result of the inflationary economy of the past few years and will they subside as the economy cools off? Quite possibly. However, the 2020 Segal study showed a pattern of losses from pay increases during the prior 4 years. Nevertheless, Segal only recognized ⅓ of the difference between the prior actuary's assumption and actual experience. Thus, it appears that a significant portion of the losses during 2021-2023 are the result of the adopted actuarial assumption significantly underestimating pay increases even in normal times.

## New entrant losses

About 38% of the losses are attributable to the valuation not anticipating that new entrants will accrue service during the year. This does not represent an understatement of existing plan liabilities. Rather, it represents non-recognition of liabilities that are expected to accrue during the ensuing year. Offsetting these liabilities are the contributions that have not been anticipated in the valuation. They offset about 77% of the new entrant loss. However, under the Plans' methodology, the losses from the new entrants are amortized over 30 years, while the gains from the excess contributions are amortized over 25 years. This mismatch seems inappropriate and leads to modest underfunding.

## Employee turnover

The GRS study indicated that the employee turnover assumptions probably overstate expected turnover in general, and especially during the first years of employment.

## Other sources

There is a consistent pattern of modest actuarial losses from unidentified sources. Over the past three years, they have totaled approximately 0.4% of the Plans' liabilities. The Plans' actuary might be asked to determine the primary sources of these consistent losses.

## Timely review of actuarial experience

The GRS report had recommended that the scheduled 2024 review of actuarial experience be accelerated to 2022 and that consideration be given to strengthening certain demographic assumptions (i.e., increasing the actuarial accrued liability). Neither of those actions took place. In fact, the Annual Comprehensive Financial Report of Colorado PERA makes no mention of the GRS report.

## Conclusions and observations

Taking all of the above into consideration, it is quite likely that the reported actuarial accrued liability of the Colorado PERA has been materially understated.

Without further analysis, it would be difficult to estimate the level of understatement. However, if the trends of the past three years, since the adoption of the demographic assumptions emanating from the 2020 Segal study, continue, it would not be surprising to see the true liabilities to be 10%, or more, higher than reported.

However, this is a crude estimate. The Plans' actuary should model liabilities based on the actual demographic experience under the Plans over the past eight years, so as to smooth out short term fluctuations.

## Other observations

- Virtually all of the Normal Cost (the actuarial cost attributed to current service) is covered by the employee contributions. The vast majority of the employer contributions are attributed to unfunded past service liabilities. However, it should be noted that the combination of the actuarial cost method (Entry Age Normal) with employee turnover (withdrawal) assumptions that have very high expected employee turnover during the first few years of employment result in: (i) a lower Normal Cost and (ii) a higher calculated actuarial accrued liability.
- As of December 31, 2023, the Unfunded Actuarial Accrued Liability ($27.5 billion) was about 2.4 times the annual payroll of the active participants. This represents a very substantial liability in relation to payroll. Interest alone (at the 7.25% valuation interest rate) totals almost $2.00 billion per year. The actual employer contributions for 2023 totaled $2.22 billion. Thus, 90% of the employer contributions went just to pay interest on the Unfunded Actuarial Accrued Liability. Exacerbating this analysis, the Unfunded Actuarial Accrued Liability was determined based on the excess of the Actuarial Accrued Liability over the Actuarial Value of Assets, which is a value that smooths out recognition of investment gains and losses. Had the Unfunded Actuarial Accrued Liability been determined using the Market Value of Assets, it would have been $2.93 billion larger, or about $30.4 billion. Interest at 7.25% on $30.4 billion would be $2.20 billion, or about 99% of employer contributions for the prior year.
- The actuarial assumption with respect to the probability that vested terminated participants will withdraw contributions, as opposed to leaving them on account in order to collect a pension, is a flat 35%. There is no differentiation based on age or service. It would seem likely that older participants who are closer to retirement, especially those with longer service and more meaningful potential retirement benefits, would leave contributions in the plan and elect a pension, as opposed to younger/shorter service participants. This could lead to actuarial losses and an understatement of plan liabilities.
- The actuary should undertake stochastic modeling of any automatic pension payment adjustments based on the Plans' investment performance. Any assumption setting based on a deterministic analysis would probably result in an inappropriate assumption.

# Part C
# Economic Assumptions

This Part sets out our analysis of the key assumptions underpinning the investment performance projections in the Segal report.

**Section C.1** provides information on our modeling and risk approach, as context for the validity of projections in subsequent sections and explains the differences between our modeling methodologies and those applied by Segal Group.

**Section C.2** evaluates capital market assumptions.

**Section C.3** evaluates the portfolio return assumption.

**Section C.4** examines return expectations under different scenarios.

**Section C.5** compares PERA's return assumption to the return assumptions adopted by pension systems across the US, to provide general context.

## Section C.1 – Our modeling and risk approach

We use a modeling and risk assessment approach which differs from those used in the Segal report. Regarding modeling, this results in more realistic simulations. In relation to risk assessment, it provides a more representative view of risk profiles for decision makers.

### PNYX/Ortec Finance modeling approach

To develop a view on portfolio performance, we construct a model portfolio reflecting our estimations of PERA's portfolio composition and utilizing the capital market assumptions as described above. We then run stochastic simulations of portfolio evolution in the Ortec Finance environment. Each simulation generates a macro environment of correlated growth and inflation conditions, and over this layer simulates asset class price developments across the simulation horizon.

The asset class prices are subject to a set of further correlations to increase the realism and validity of the simulation, including differing correlation weights over different time horizons, short-term mean-reversion, medium-term business-cycle dependency, and long-term factor dependency derived from fundamental macro aspects including country demographics and rates of technological development.

Other considerations for increasing realism include an increase in correlation among risky assets during financial crises, as well as a realistic yield curve model that accounts for interactions between short-term, medium-term, and long-term rates.

We note that the Segal systems do not model correlations between macro factors and asset class performance, potentially reducing the realism provided by that approach. This may be an area for follow-up adjustment.

Our simulations also model the skewness and kurtosis observed in real-world markets, meaning that negative swings in asset values tend to be larger than positive swings. This differs from the

Segal approach, which models volatility using a normal distribution, implying an expectation of symmetric movements in both positive and negative directions, and may be overly optimistic. Instances of extreme negative events, in terms of both frequency and magnitude, occur more frequently than expected under a normal probability distribution. Our modeling approach incorporates this characteristic.

In Segal's simulation, it is assumed that each asset class follows a normal distribution. The report does not mention the correlation between asset classes or changes in correlation over time. Segal's approach bases the simulations on portfolio return and portfolio volatility only, with volatility assumed to be symmetrical. The distribution of simulated results is set out in the Segal report and extracted below in Figure 5.

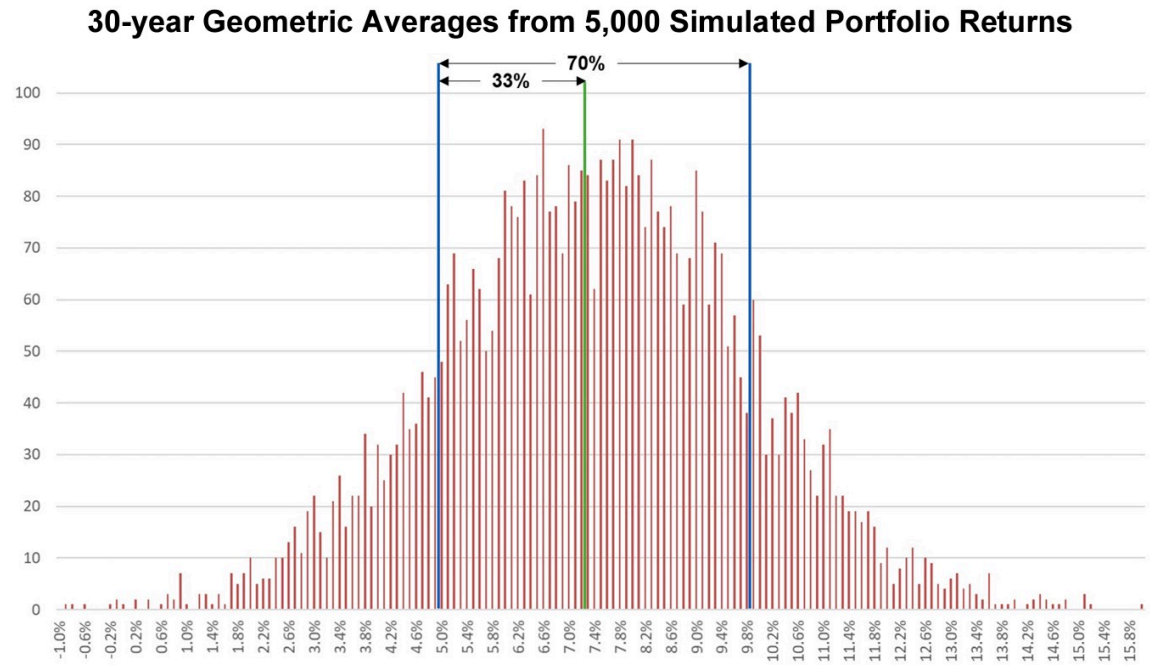



*Figure 5*

Source: Segal 2022 Signal Light Report, page 18

For comparison, Figure 6 shows the S&P 500 rolling 1-year return distribution alongside the normal distribution that attempts to approximate it, using only the average return and volatility. The approximation using the normal distribution clearly underestimates the likelihood of extreme negative returns.

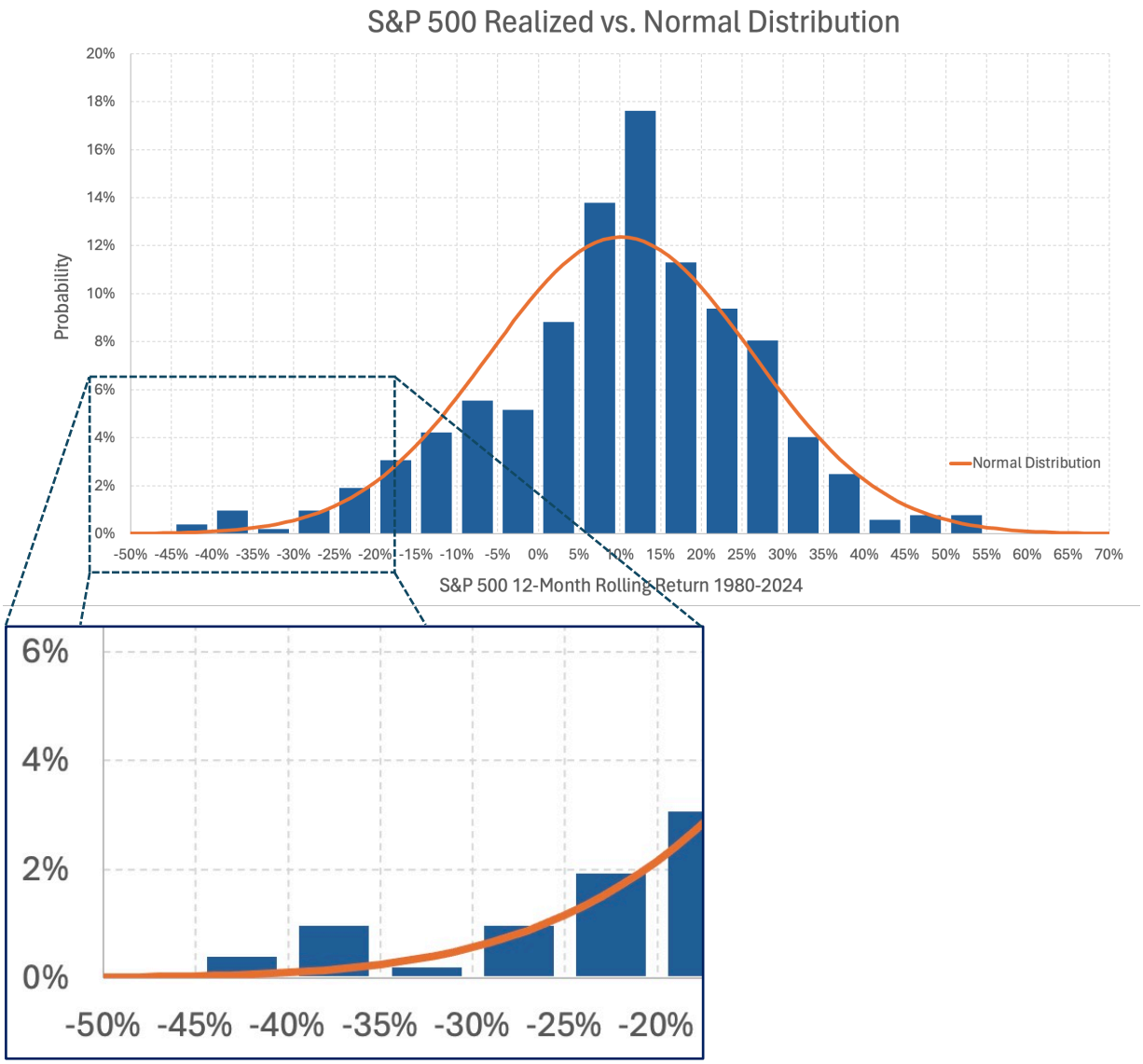



*Figure 6*

A summary of differences between the two modeling approaches is set out in the Annex.

## Risk measures

At PNYX we prefer not to use the typical measure of risk – volatility or standard deviation. We consider that, especially for institutional asset owners, standard deviation is an inadequate risk measure. This is because it treats all deviations from the mean equally, failing to distinguish between positive and negative returns. This symmetrical treatment can be misleading, especially where an investment objective is sensitive to downside risk more than upside variability. The emphasis on tail risk—extreme negative outcomes—is critical for institutional investors managing large portfolios which must avoid falling below a certain threshold.

This issue is compounded by an assumed symmetry of a return distribution which does not reflect actual asset performance. Returns empirically show a negative skew with fat negative tails. Typical modeling does not account for these extreme events. Combined with a standard

deviation risk measure, this can lead to significant underestimation of potential losses, making it ineffective for capturing the true risk profile of a portfolio.

Since the Segal report includes standard deviation as a risk measure, we have included it for comparison in our analyses in this report. However, our preferred measures are CVaR and P25/75. We have included these measures as they give a better and more nuanced picture of portfolio risk, which we consider important in making policy choices. A description of each is set out below.

## Conditional Value at Risk (CVaR)

Conditional Value at Risk (CVaR) is a risk measure used to evaluate a portfolio's potential loss by assessing the likely extent of loss in extreme conditions. The CVaR value reflects the expected loss exceeding a specified Value at Risk (VaR) threshold. Unlike VaR, which only indicates the maximum loss expected with a certain confidence level, CVaR focuses on the tail end of the loss distribution. This provides a view on the average loss a portfolio could face in the worst-case percentile of returns – in our case, the worst 5% of cases. One way of interpreting a 5% CVaR is the extent of the loss that could occur in the worst year of a 20-year period.

One significant advantage of CVaR over standard deviation (volatility) is that CVaR directly addresses the potential for extreme losses. Standard deviation measures the dispersion of returns around the mean, treating deviations in both directions equally. This approach fails to distinguish between upside and downside risks, which can be misleading in assessing the true risk of a portfolio. CVaR, on the other hand, focuses on the downside risk by considering the average loss in the worst scenarios. This provides a clearer understanding of potential catastrophic losses, a critical aspect of a valid risk picture.

## P10 and P90

The P10 and P90 risk measures represent the 10th and 90th percentiles of a portfolio's return distribution, respectively. The P10 measure indicates the return below which the worst 10% of outcomes fall, highlighting downside risk, while the P90 measure shows the return above which the best 10% of outcomes fall, indicating potential for exceptional gains.

Like CVaR, these risk measures focus on the distribution tails. Unlike standard deviation, which (as noted above) assumes a normal distribution and captures overall volatility without differentiating between upside and downside risk, P10 and P90 measures directly address the tails of the distribution. This makes them useful in identifying the degree of asymmetry in returns and therefore the risk of outsize losses, information not captured by standard deviation. In turn, this provides a more nuanced risk picture and allows for more tailored risk management.

# Section C.2 - Capital market assumptions

## Segal capital market assumptions

Segal's capital market assumptions from the 2023 Signal Light Report (which covers results up to 31 December 2022) are set out in Table 2.[1] As noted in the Segal report, these were long-term assumptions provided by Aon Hewitt, Segal's investment consultant, which date from early 2019. This means that there is likely to be some variation from how Aon/Segal would estimate these values now.

*Table 2*

| Asset Classes[1] | Long-Term Asset Allocation[1] | Expected Nominal Return[1] | Expected Risk[1,2] |
|---|---|---|---|
| Global Equity | 53.0% | 8.00% | 19.00% |
| Fixed Income | 23.0 | 3.60 | 5.00 |
| Real Estate | 8.5 | 6.65 | 20.00 |
| Private Equity | 8.5 | 9.60 | 24.50 |
| Opportunity Fund[3] | 6.0 | 7.12 | 9.46 |
| Cash | 1.0 | 2.70 | 2.00 |
| Inflation | | 2.30 | |
| **Total Fund:** | | | |
| Expected Return | | 7.47% | |
| Expected Risk | | 13.00% | |

[1] Based on the existing long-term asset allocation and the 30-year capital market assumptions as of the first quarter 2019, as provided by PERA's investment consultant, Aon Hewitt. This assumption set was used in the 2019 asset liability study and displayed in the "Asset-Liability Study Follow-Up" presentation, dated September 13, 2019.

[2] Expected risk is represented by the standard deviation of results.

[3] Effective January 1, 2020, the asset class titled "Opportunity Fund" was changed to "Alternatives" within PERA's asset allocation.

Source: Segal 2022 Signal Light Report, page 14

## PNYX capital market assumptions

To develop a comparative set of assumptions for each asset class, PNYX uses Ortec Finance GLASS to model the expected capital market behavior of that asset class. Ortec Finance GLASS is an Asset Liability Management (ALM) tool that provides consistent and flexible modeling of future development of assets and liabilities. It is developed by experts in the fields of econometrics and technology and is used by more than 600 institutional clients globally.

We have modeled the classes on the following bases:

- **Global equity:** the following geographic areas have been taken into account: US, Canada, Europe, Japan, APAC ex Japan, Emerging.

[1] The 2024 report had not been released at the time of writing.

- **Fixed income:** a blend of US government and US corporate bonds that have a rating and duration comparable to the benchmark Bloomberg U.S. Aggregate Bond Index.
- **Real estate:** private real estate core investment in the US.
- **Private equity:** a mix of private equity and venture capital investments in the US and Europe.
- **Opportunity fund/Alternatives:** a mix of minimum volatility strategy, inflation sensitive strategy and relative value strategy.

The resulting expected nominal return and risk profiles for each asset class are set out in the table below.

Table 3 includes tail risk measure (CVaR) which is different from those in the extract from the Segal report above and which is described in Section C.1 above, and the expected returns are also obtained using the different methodology described in that Section.

*Table 3*

| Asset class | PNYX expected nominal return | PNYX expected std dev (volatility) | PNYX CVaR |
|---|---|---|---|
| Global Equity | 7.26% | 17.55% | -31.17% |
| Fixed Income | 4.11% | 6.87% | -9.57% |
| Real Estate | 7.01% | 19.17% | -29.38% |
| Private Equity | 9.59% | 30.87% | -40.78% |
| Opportunity Fund / Alternatives | 7.08% | 8.14% | -10.70% |
| Total Fund | **6.71%** | **12.47%** | **-20.34%** |

Source: PNYX/Ortec Finance

The Total Fund return assumes the application of the Long-Term Target Asset Allocation. Based on the actual allocation as of December 31, 2023, the Total Fund return is expected to be 6.71%. If the actual portfolio allocation as of end-2023 is used (which has a fixed income allocation close to the lower band limit), the expected return is 6.84%.

The PNYX expected return for each asset class is derived from forward-looking simulations. Each simulation incorporates short-term, medium-term, and long-term projections, along with stylized facts (on which more details are set out in the Annex).

## *Analysis* of assumption validity

As noted above, the assumptions in the Segal report dated from early 2019, a period with a very different economic environment compared to 2023 in terms of growth expectations, inflation expectations, and central bank monetary policy.

In early 2019, the global economy was experiencing steady growth, with moderate inflation and relatively stable central bank policies. By 2023, the economic landscape had shifted dramatically. The COVID-19 pandemic, geopolitical tensions, supply chain disruptions, and fiscal stimulus measures led to heightened economic uncertainty and significant policy adjustments. Growth expectations became more volatile, influenced by recovery phases and

varying responses to economic shocks. Inflation surged due to supply constraints and increased demand, prompting central banks, including the Federal Reserve, to adopt more aggressive monetary policies to combat rising prices.

Given these changes, the models and assumptions used in early 2019 would likely require appropriate revisions.

# Macro assumptions

## Inflation

Segal/Aon Hewitt modeling includes an inflation expectation of 2.3%. Across our stochastic simulations, our Ortec Finance model uses a long-term inflation rate of 2.12%.

**Ortec Finance trend indicator for inflation**

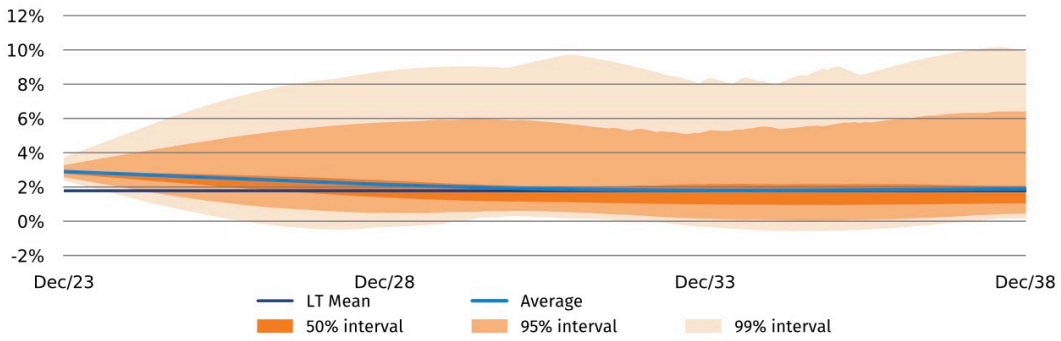



*Figure 7*

Source: Ortec Finance

The combination of extraordinary health, economic, geopolitical, and climate transition, and fiscal conditions and the associated macroeconomic, strategic and monetary policy responses to them suggests that inflation uncertainty will remain elevated in the short run. In the long run, it is assumed that (core) inflation gradually converges towards central bank targets due to policy action.

Given the similarity of the two figures, we do not consider that it is essential to adjust the existing inflation assumption, though PERA may wish to ensure clarity on how the inflation assumption is derived.

## Real GDP Growth Rate

The long-term GDP growth rate is estimated using well-established economic models that consider factors such as productivity, capital stock, labor, and human capital. It also considers developments such as climate change and the combination of unprecedented fiscal stimulus in the past decade (and its unwinding) with high public and corporate debt, which add significant uncertainty to the long-term outlook. Over a 30-year time horizon, the estimated real US GDP growth rate is 1.83%. The chart below shows the modeling evolution of GDP growth.

The chart below shows the long-term projection.

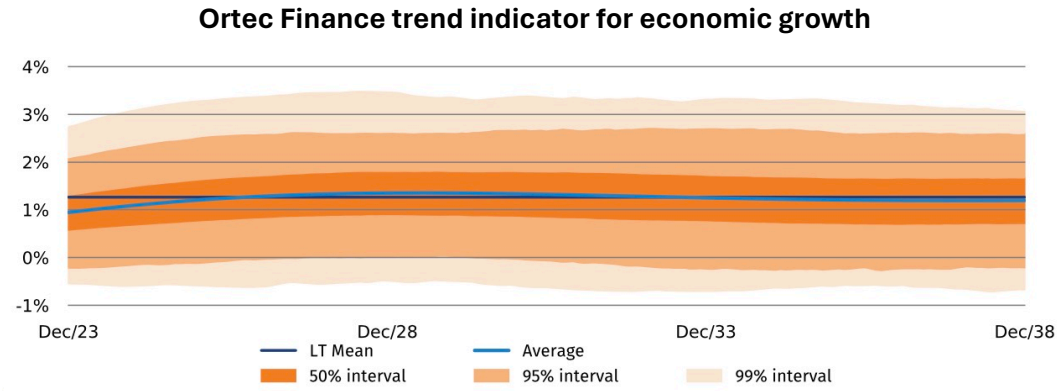



*Figure 8*

Source: Ortec Finance

# Section C.3 - Portfolio performance and return assumptions

PERA has adopted an expected rate of return of 7.25%. To evaluate the validity of this figure, we compare the 7.25% return assumption with a PNYX model of the PERA portfolio under the current and projected economic conditions.

## PNYX portfolio performance projections

The following chart shows our portfolio return simulations over a 30-year horizon and illustrates the range of potential portfolio outcomes as well as our median return.

Each portfolio outcome is a realistic simulation incorporating a range of economic and financial variables, including assets and liabilities. This enables detailed analysis under various scenarios. In this section, we focus on the median outcome.

**PERA portfolio performance projections, PNYX assumptions**

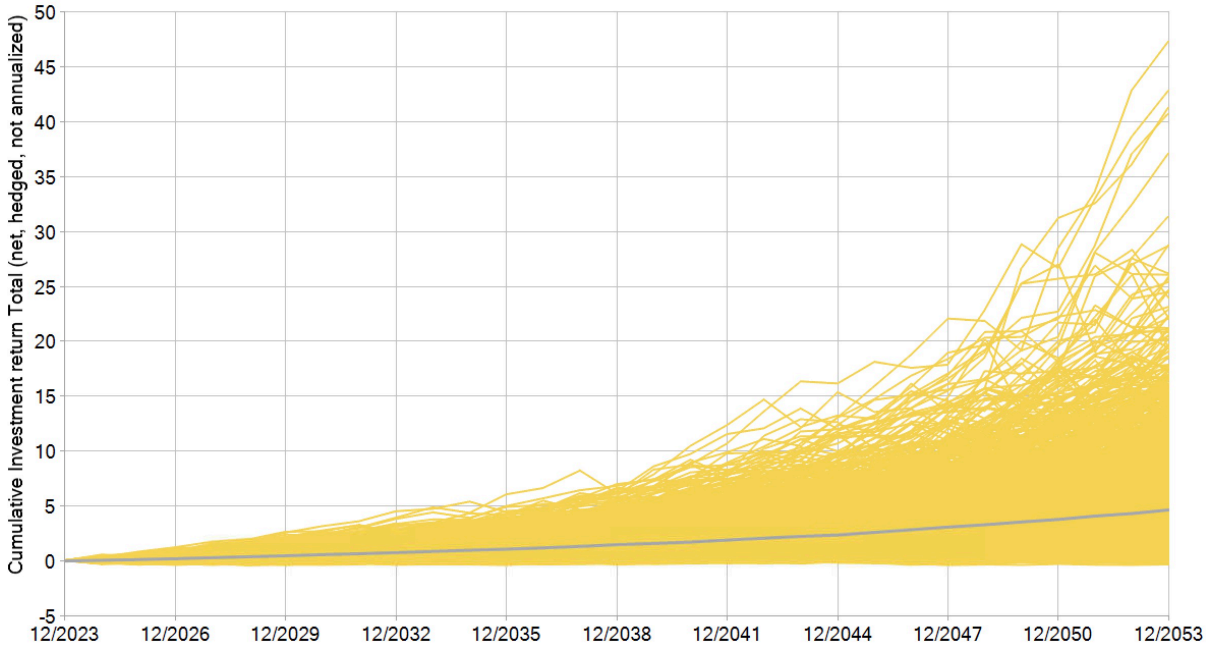



*Figure 9*

Source: PNYX/Ortec Finance

## Results

From this process we anticipate a nominal rate of return of 6.71%, with a volatility of 12.47% and a CVaR of -20.34%. Given our inflation rate assumption of 2.12%, this results in a real rate of return expectation of **4.59% over a 30-year horizon**.

**Given the long time horizon involved, this is materially lower than the assumed 7.25% nominal and 4.95% real return assumed by PERA**. If our further analysis confirms these figures, we expect that we would recommend that PERA revises its adopted rate of return.

# Section C.4 - Return expectations under different scenarios

The view of potential portfolio performance can be significantly enhanced by reviewing performance under specified scenarios.

To provide this context, we selected a set of economic scenarios focusing on future growth and inflation. The scenarios are higher and lower growth, higher and lower inflation, and stagflation. Other more complex scenarios are possible to evaluate the portfolio's sensitivity to evolutions in (for example) climate, geopolitical or governance factors. This is particularly relevant if PERA has a set of convictions about how such economic or other factors might evolve.

The scenarios show portfolio sensitivity to top and bottom decile US GDP growth (the high and low growth scenarios respectively), and top and bottom decile inflation (similarly, high and low inflation scenarios respectively). The factors can also be blended, and we include a combination of low growth and high inflation to evaluate a stagflation scenario.

The portfolio performance expectations under each scenario differ from our baseline expectation as shown in Figure 10 and Table 4. The table also shows the average GDP growth figure or inflation figure applied in each scenario.

**Portfolio characteristics under different scenarios**

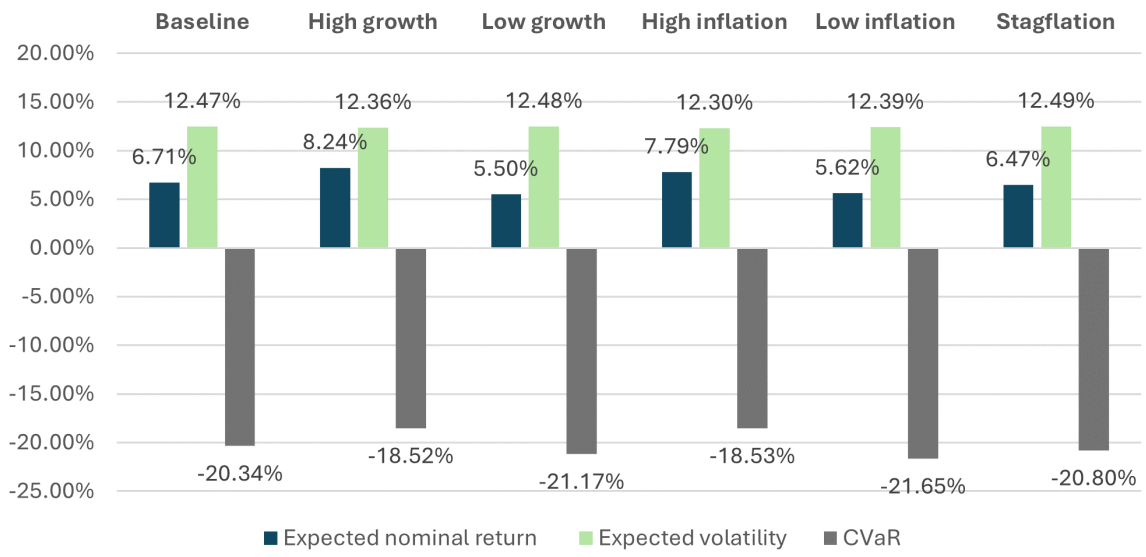



*Figure 10*

*Table 4*

| Scenario | Description | Expected nominal return | Deviation from baseline | Expected volatility | CVaR |
|---|---|---|---|---|---|
| Baseline | all simulations | 6.71% | | 12.47% | -20.34% |
| High growth | top 10% GDP (*avg. 2.98%*) | 8.24% | 1.53% | 12.36% | -18.52% |
| Low growth | bottom 10% GDP (*avg. 0.72%*) | 5.50% | -1.21% | 12.48% | -21.17% |
| High inflation | top 10% CPI (*avg. 3.80%*) | 7.79% | 1.08% | 12.30% | -18.53% |
| Low inflation | bottom 10% CPI *(avg. 1.14%)* | 5.62% | -1.09% | 12.39% | -21.65% |
| Stagflation | Bottom 20% GDP with top 20% CPI (*avg. 1.09% and 3.14% respectively*) | 6.53% | -0.18% | 12.30% | -19.89% |

Source: PNYX/Ortec Finance

## Implications of scenarios

The scenario analysis shows that under low growth, low inflation and stagflation scenario, the expected returns are even lower than in the base scenario. This underscores the importance of revising the expected return. Further analysis of the scenarios is reviewed in detail in Section D.2 below.

## Analytic method

The stochastic simulation approach described in Section C.1 enables us to filter the body of simulations to isolate outcomes with certain characteristics. This means that various scenarios can be built to test the portfolio's expected performance depending on a particular forward-looking view.

The following example illustrates the concept of selecting and combining different scenarios. We define high growth scenarios as the top 10% of scenarios with the highest US GDP growth and low growth scenarios as the bottom 10% of scenarios with the lowest US GDP growth.

On the left-hand side of Figure 11, scenarios with high growth simulations are highlighted in yellow, while on the right-hand side, low growth simulations are highlighted in yellow.

**Top 10% US GDP growth simulations** **Bottom 10% US GDP growth simulations**

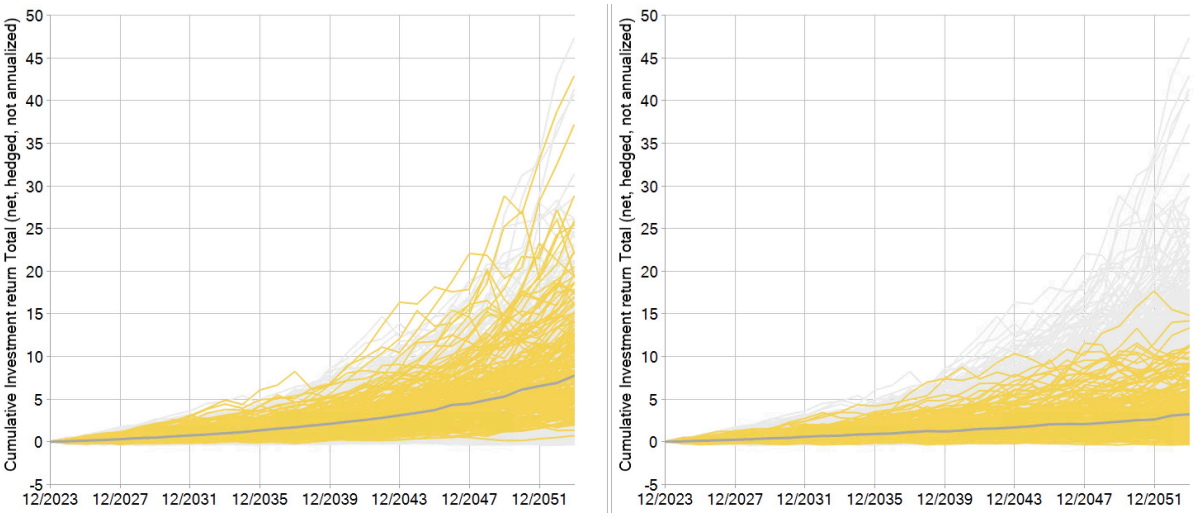



*Figure 11*

Source: PNYX/Ortec Finance

The two growth scenarios demonstrate a correlation between US GDP growth and portfolio performance. However, higher US GDP growth does not translate into higher asset return on a directly proportional basis. This is because different asset classes and various geographical allocations have different correlation coefficients to US GDP, along with along with the stochastic effects included in the simulation. This approach is advantageous over deterministic approaches. It generates more realistic simulations, providing a more reliable modeling framework overall.

## Further discussion on scenarios

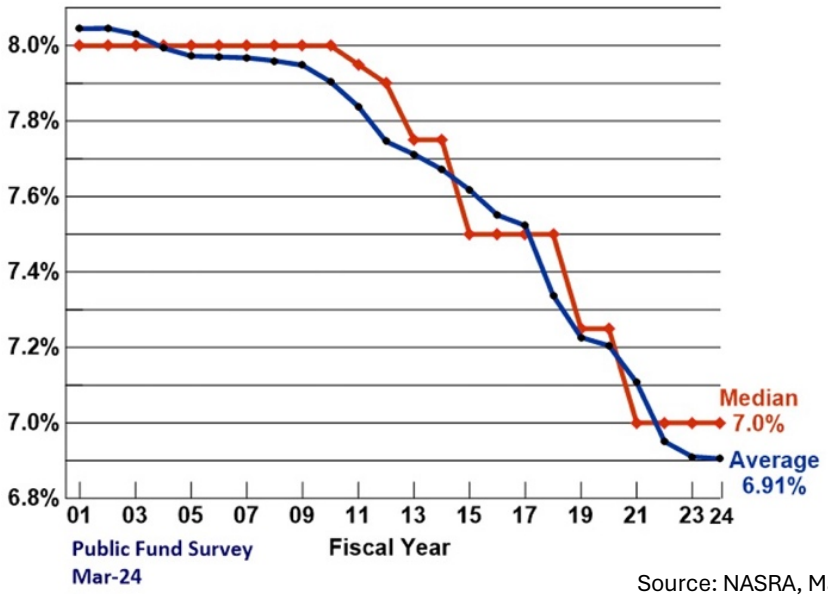
Scenario modeling can be a powerful way of developing an investment strategy that aligns with PERA's forward-looking macro views. It can then feed into risk assessment and portfolio design, and help make an optimized choice about balancing investment risk with contribution considerations. We would recommend a discussion relating to PERA's forward-looking views, so that we can determine together how to evaluate these aspects.

# Section C.5 - Contextual comparison of PERA's return assumption

For more general context, PERA's 7.25% return assumption can be compared with the return assumptions adopted by US pension systems nationwide to assess whether the PERA rate is an outlier.

The NASRA compilation of pension system return assumptions is set out in Figure 12. The data indicates that pension systems have been consistently revising their return expectations downwards almost every year since 2000.

**Change to average and median investment return assumption, FY 01 to FY 24**



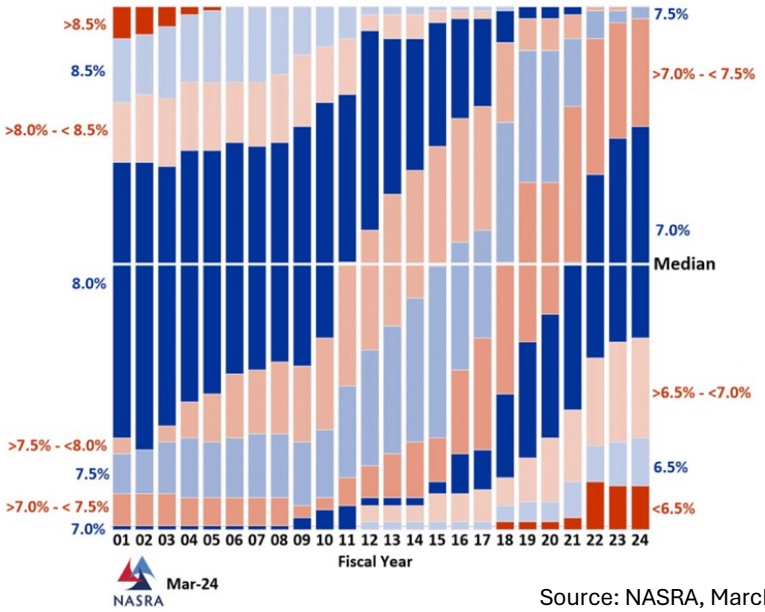

Source: NASRA, March 2024

*Figure 12*

Since 2021, median rates have been 7.0%. Given the apparent downward trend, this backdrop may provide a further reason for reviewing PERA's return expectation.

Figure 13 provides further detail of the overall composition of US pension systems' return expectations. Each color band corresponds alternatively to a specific rate, or a 0.5% rate band, as labelled on the left and right axes. Expectations of a return between 7.0% and 7.25% have gone from representing the median view between 2018 and 2021 to representing a relatively smaller percentage of pension systems.

**Change in Distribution of Nominal Public Pension Investment Return Assumptions, FY01-24**




Source: NASRA, March 2024

*Figure 13*

# Part D
# Timing to full funding

A critical question for the Subcommittee is whether PERA is on track to achieve its funding target of full funding by 2048.

In this section we briefly review the Segal 2023 projections (included in the 2023 ACFR) and compare with our projections for the horizon to achieving full funding. We then evaluate the probability of achieving this, based on our economic expectations discussed in Part C.

Our analysis indicates that PERA is not on track to reach the funding target by 2048.

## Section D.1 - Timing for achieving the funding target

### Segal Group projections

The most recent Segal report projections show PERA's division funds as being on track to reach 100% funded by 2048, with the exception of the School Division.

*Table 5*

| Trust Fund | Projected Years[2] Until 100% Funded |
|---|---|
| State Division | 23 years |
| School Division | 27 years |
| Local Government Division | 14 years |
| Judicial Division | 8 years |
| DPS Division | 9 years |
| HCTF | 9 years |
| DPS HCTF | N/A |

[2] Calculations completed on a projected basis with an open, increasing population (i.e., active members expected to retire, terminate, or die are replaced by new members who will accrue pension benefits under a lower cost basis).

Source: 2023 Annual Comprehensive Financial Report

However, the annual horizon projections present a significant degree of volatility as in Table 6.

*Table 6*

| | Projected Years Until 100% Funded | | |
|---|---|---|---|
| | Dec 2023 | Dec 2022 | Dec 2021 |
| State Division | 23 | 32 | 16 |
| School Division | 27 | 34 | 16 |
| Local Government Division | 14 | 23 | 2 |
| Judicial Division | 8 | 12 | 3 |
| DPS Division | 9 | 13 | 2 |

Source: 2023 Annual Comprehensive Financial Report, Segal 2022 and 2021 Signal Light Reports

The change in each year, which is correlated with changes in asset returns, appears to demonstrate the fund's sensitivity to asset returns. This is a natural consequence of its negative cash flow position.

## Comparison of Segal median funding paths with PNYX analysis

Figure 14 shows our modeling of the funded ratio of each PERA division and the fund total, using the current actuarial cash flows and the adopted 7.25% return. In this scenario, the total fund will achieve full funding in 24 years from 2023, that is, in 2047.

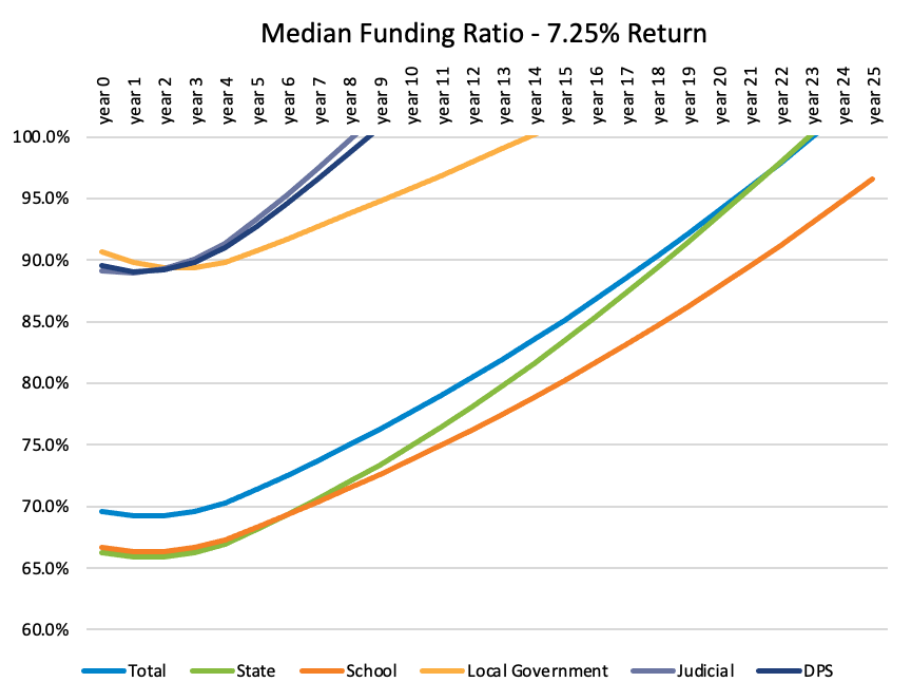



*Figure 14*

Source: PNYX/Ortec Finance, 2023 PERA cash flows

When using the median projected returns derived from the PNYX/Ortec Finance modeling of economic factors, there are delays in State and School division. The total fund ratio reaches 100% in year 2049, a 2-year delay.

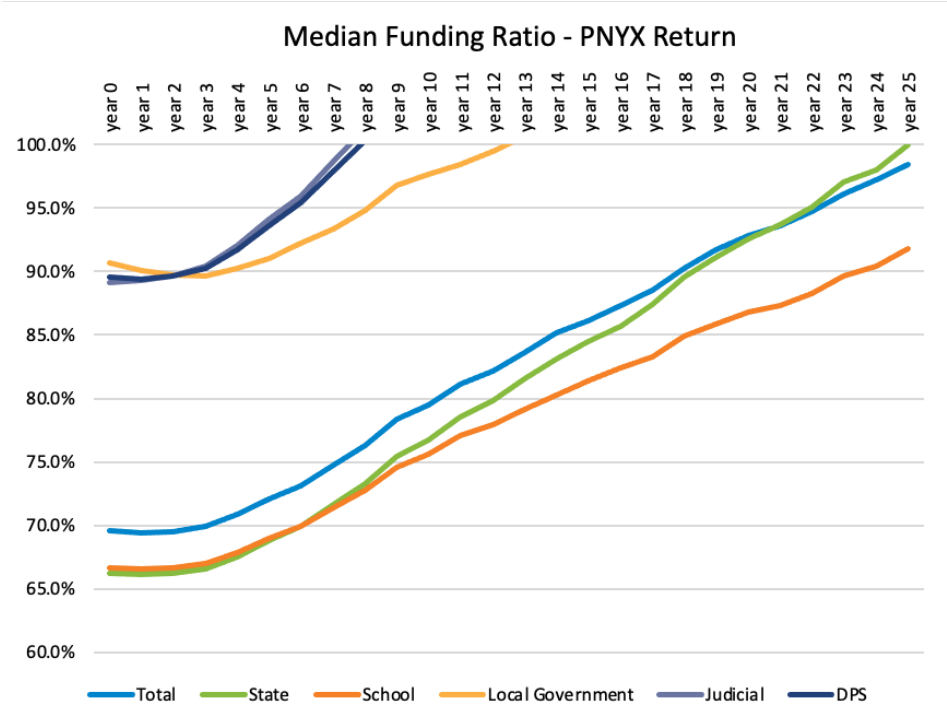



*Figure 15*

Source: PNYX/Ortec Finance, 2023 PERA cash flows

The impacts are pronounced in the School division, with a delay of five years to full funding using PNYX/Ortec Finance market assumptions and simulations.

*Table 7*

| | Projected Years Until 100% Funded | |
|---|---|---|
| | 7.25% flat | PNYX |
| State Division | 23 | 25 |
| School Division | 27 | 32 |
| Local Government Division | 14 | 13 |
| Judicial Division | 9 | 8 |
| DPS Division | 9 | 8 |
| **Total** | **24** | **26** |

Source: PNYX/Ortec Finance

## Practical validity of median timing projections

The timing of the median path to 100% funding is one metric of whether the fund is on track to meet the funding objective. However, this needs to be viewed in the context of the probability that fund performance will match the median.

In PERA's case, there is a high probability that it will not. This is already apparent from signal light assessments in the Segal report and is examined in the following Part. It shows that there is a high degree of dispersion around the median return figures and that the risk of serious negative outcomes is material.

# Section D.2 - Probability of achieving the funding target

Our model of PERA's funded ratio evolution is set out in Figure 16.

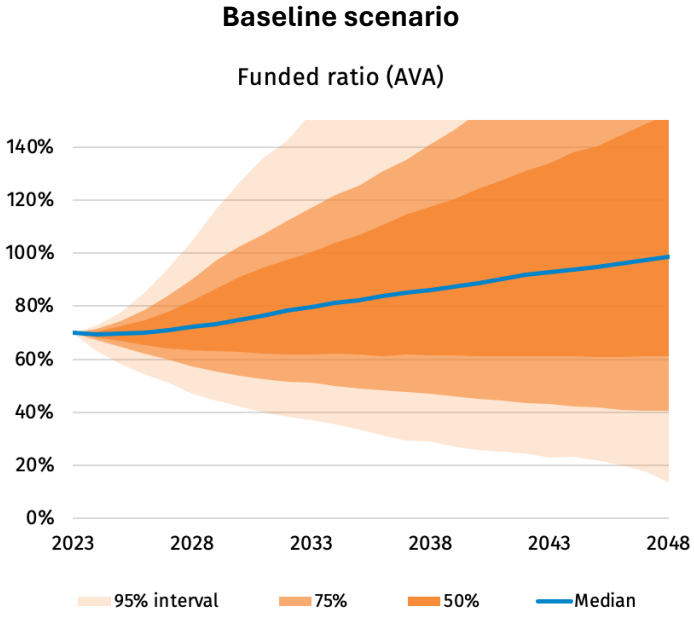



*Figure 16*

Source: PNYX/Ortec Finance

The chart presents very wide dispersion. This is related to the need to achieve a relatively high rate of return over a sustained period, which is exacerbated by PERA's negative cash flow. Table 8 illustrate the wide dispersion of the funded ratio.

*Table 8*

| **Scenario** | **Description** | **Funded ratio median** | **Funded ratio P10** | **Funded ratio P90** |
|---|---|---|---|---|
| Baseline | all simulations | 99% | 36% | 216% |
| High growth | top 10% GDP (*avg. 2.98%*) | 136% | 60% | 259% |
| Low growth | bottom 10% GDP (*avg. 0.72%*) | 72% | 21% | 198% |
| High inflation | top 10% CPI (*avg. 3.80%*) | 70% | 26% | 166% |
| Low inflation | bottom 10% CPI (*avg. 1.14%*) | 97% | 43% | 224% |
| Stagflation | Bottom 20% GDP with top 20% CPI (*avg. 1.09% and 3.14% respectively*) | 54% | 25% | 119% |

Source: PNYX/Ortec Finance

## Funded ratio evolution under various scenarios

By applying the scenarios described in Section C.4 above, we can gain some further perspectives around the risks and the probabilities of achieving full funding by a given horizon. The charts in Figure 17 illustrate funded ratio dispersion under different scenarios, as well as a chart comparing the median funded ratio across scenarios.

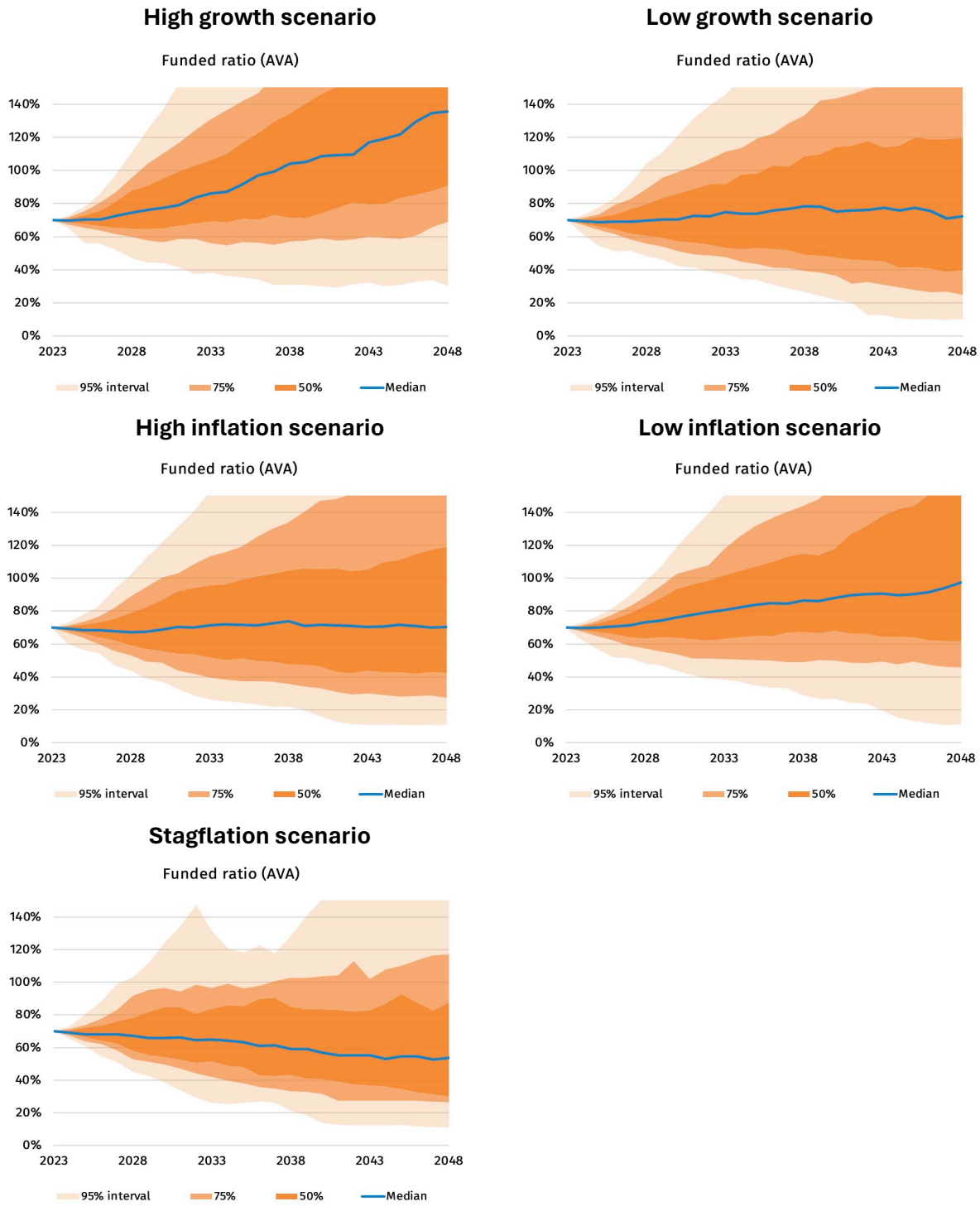



*Figure 17*

Source: PNYX/Ortec Finance

Under our forward-looking simulations that incorporate all economic variables, it is possible to filter out different scenarios for further analysis. Both the central simulation and dispersions can be analyzed under each scenario.

Due to the plan's maturity and negative cash flows, a high degree of dispersion can be observed across all scenarios. The scenarios indicate that the funded ratio is positively correlated with US GDP growth. Higher growth positively impacts assets, while liabilities remain stable, resulting in an improved funded ratio. Conversely, if US GDP growth is low, it negatively impacts asset classes. Combined with stable liabilities, this results in a lower funded ratio.

When examining inflation scenarios, the impact is not as dramatic as with the growth factor, though there is still a clear difference. Inflation affects both the asset side (e.g. global equity, real estate, and private equity) and the liability side, meaning that its impact should be expected to be more attenuated than the impact of growth. The simulation shows that under high inflation scenarios, the funded ratio does not improve over time, as the positive impact on the asset side is offset by the increase in liabilities. Conversely, under low inflation scenarios, the funded ratio improves over time. This could be because liabilities, which are higher than the assets, increase at a slower rate, leading to an improved funded ratio.

The stagflation scenario, characterized by low growth and high inflation, is the worst case. The combined effect of lower returns and a higher increase in liabilities compared to assets leads to a deterioration of the funded ratio over time.

It is worth noting that the median projections under the low growth, high inflation, and stagflation scenarios never reach 100% funded, and the risk of insolvency is significant. Even in the low inflation scenario, the risk of insolvency remains non-negligible.

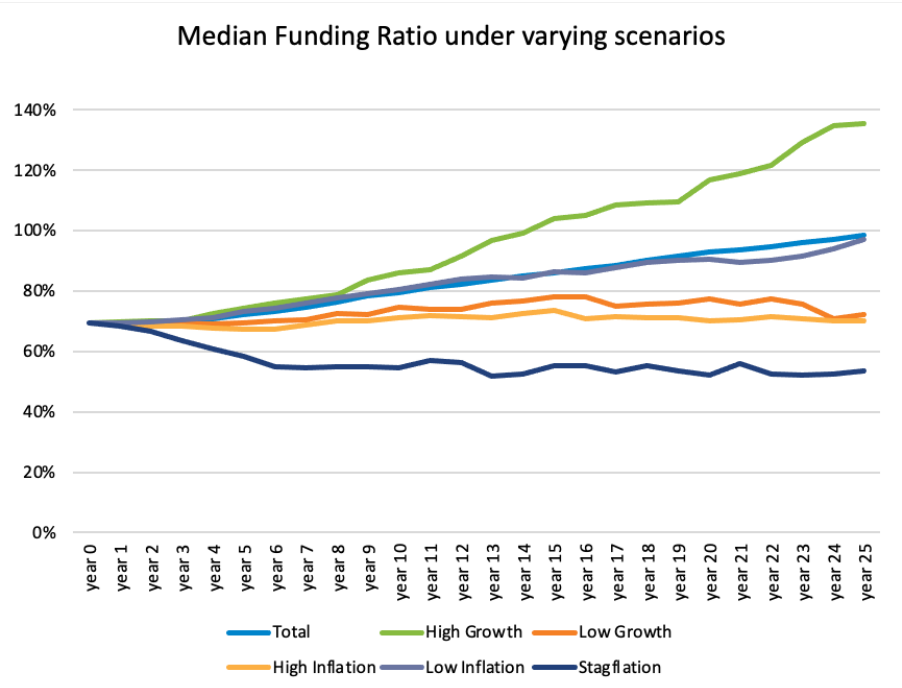



*Figure 18*

Source: PNYX/Ortec Finance

## Compatibility with risk appetite

A potential point for further discussion will be how the dispersion shown in the charts above, whether under the baseline or under relevant scenarios, interacts with PERA's risk appetite, which should reflect a combination of the risk appetite of plan members and the fund's characteristics (as set out in Part A), such as fund maturity and net cash flow. While this may be a position with which PERA is comfortable, and the wide dispersion is necessary to have a satisfactory probability of achieving 100% funding within the target horizon of 2048, it also presents a significant probability of severe underperformance or fund insolvency (a funded ratio of below 50%).

## Probability of reaching the funding target under the Signal Light format

Segal's Long-Term Signal Light reports present the probability of achieving the funding targets in a different format. To help assess the validity of these figures, we have presented the output of our funded ratio model in the signal light format for each division in the Annex.

# PART E
# Options for improving PERA's funding position

This part considers a set of different options that decision makers may consider in order to improve PERA's sustainability and funding position. The options are as follows:

**Option E.1** Revised asset allocation making full use of existing bands

**Option E.2** Lump sum contribution to the plan

**Option E.3** Establish a parallel fund under a separate regime and strategy, to cover future funding shortfalls

**Option E.4** Increase non-state contributions

## Option E.1 – Revised asset allocation within existing bands

In this option, we evaluate the potential for an optimized asset allocation that within PERA's existing bands. We evaluate the impact of two optimizations: one to maximize return (with the objective of accelerating the time to full funding) and the other to minimize risk (with the objective of minimizing the possibility of reaching a point of no return, being less than 50% funding).

### Characteristics of the existing asset allocation

PERA's strategic asset allocation is as follows:

*Table 9*

| | 2023 Policy Benchmark Weight | Long-Term Asset Allocation Target | Target Range |
|---|---|---|---|
| Global Equity | 54.0% | 54.0% | 48.0% – 60.0% |
| Fixed Income | 23.0% | 23.0% | 18.0% – 28.0% |
| Private Equity | 8.5% | 8.5% | 4.0% – 13.0% |
| Real Estate | 8.5% | 8.5% | 4.0% – 13.0% |
| Alternatives | 6.0% | 6.0% | 0.0% – 12.0% |

Source: 2023 Annual Comprehensive Financial Report, page 124

One feature of the structure is that the scope for adjustment within the bands is relatively limited, as the portfolio is effectively 74% allocated (as this is the sum of all minimum weights). As a separate exercise it may be worthwhile to consider whether widening the bands could provide better optimization for policy goals, in particular of downside risk management.

As of December 31, 2023, the actual asset allocation indicates that Fixed Income is underweighted near the lower band. Global Equity, Private Equity and Alternatives investments are slightly overweighted compared to the Long-Term Asset Allocation Target, and Real Estate is

overweighted. We have given further attention to the Fixed Income and Private Equity allocations in the following sections.

## Bond portfolio

We understand that for PERA a key purpose of the Fixed Income allocation is to provide diversification benefit, which is a typical objective of a Fixed Income allocation along with periodic income generation.

To evaluate the Fixed Income portfolio's diversification effect, we conducted an unconstrained optimization (allowing a range of 0-60% allocation for each asset class). The results show that over the next 30 years, fixed income investments provide a diversification effect and are preferred in a portfolio targeting an expected return between 6.5% and 7.5%. For higher expected return portfolio, fixed income is not considered as efficient allocation.

*Table 10*

| **Expected Portfolio Return** | **6.50%** | **7.00%** | **7.50%** | **8.00%** |
|---|---|---|---|---|
| Optimized Fixed Income Allocation | 26% | 15% | 5% | 0% |

Source: PNYX/Ortec Finance

On this basis, the allocation appears reasonable given PERA's 7.25% return target.

For context, we compared the allocation to Fixed Income to the allocations made by the sample of 228 US pension plans referred to elsewhere in this report. The current allocation of 18.9% is close to the median allocation of 21.28%, though we note that this figure dates from 2022.

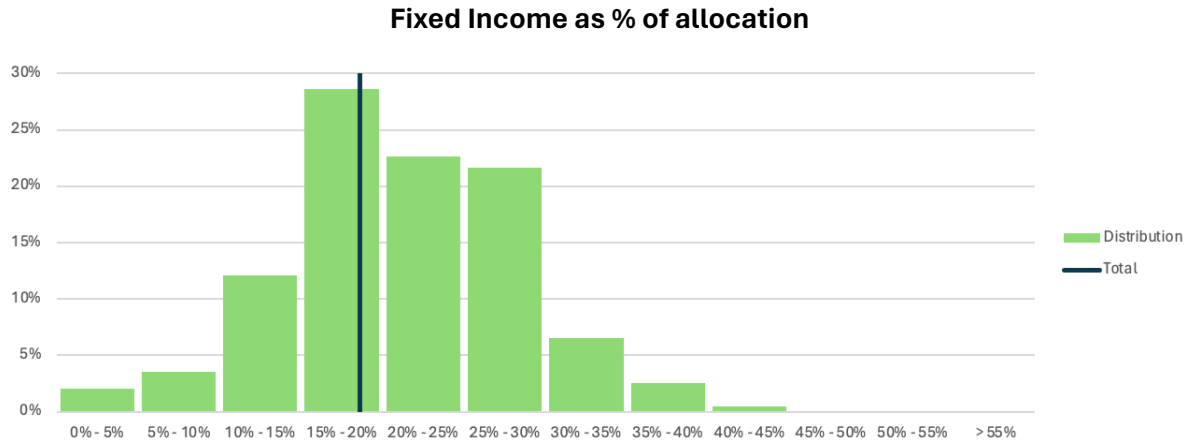



*Figure 19*

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

Regarding the portfolio's duration, PERA uses the Bloomberg Barclays U.S. Aggregate Index as its benchmark. This broad bond index composes primarily of U.S. Treasury securities, U.S. mortgage-backed securities, and investment-grade corporate bonds. It is one of the most widely used benchmarks for this purpose, with a modified duration of 6.31 as of the end of 2023.

PERA's approach to managing the Fixed Income portfolio appears to follow the composition of the benchmark quite tightly. It would be open to PERA to manage the portfolio more actively. One approach would be to overweight shorter-duration instruments, in order to reduce the portfolio's duration and reduce sensitivity to interest rate fluctuations.

## Private equity

The same unconstrained optimization shows that over the next 30 years, private equity is preferred for portfolios targeting a higher return. PERA's allocation to private equity is 8.7%.

*Table 11*

| **Expected Portfolio Return** | **6.50%** | **7.00%** | **7.50%** | **8.00%** |
|---|---|---|---|---|
| Optimized Private Equity Allocation | 7% | 15% | 23% | 37% |

Source: PNYX/Ortec Finance

As with Fixed Income above, we run an unconstrained optimization to evaluate the potential optimal allocation to private equity. The unconstrained optimization is intended to demonstrate the relative attractiveness of each asset class only. A complete asset allocation exercise would of course consider additional criteria such as liquidity requirements, minimum yield, and various other factors.

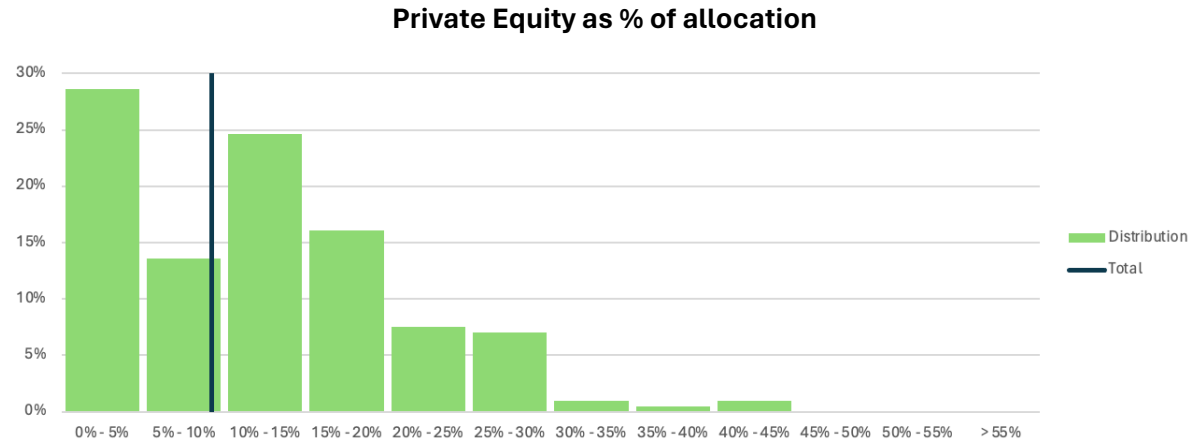



*Figure 20*

Source: PNYX, using data compiled from publicplansdata.org as of December 31, 2022

As of 2022, median U.S. pension funds allocated 12.00% to private equity. PERA's allocation is below this median, and given the potential for private equity to provide higher returns, this allocation could in principle be increased.

## Objectives of a revised portfolio

The revised optimizations are intended to either maximize the likelihood that PERA's investment returns achieve or exceed the target 7.25%, while also avoiding reaching a point of no return (which we define as a funded ratio at or below 50% funded).

## Baseline allocation

The current allocation with a Long-Term Asset Allocation Target is as follows:

*Table 12*

| | Weights | Exp. Ret. | Exp. Vol. |
|---|---|---|---|
| **Total assets** | **100.00%** | **6.71%** | **12.47%** |
| Global Equity | 53.90% | 7.26% | 17.55% |
| Fixed Income | 23.00% | 4.11% | 6.87% |
| Private Equity | 8.60% | 9.59% | 30.87% |
| Real Estate | 8.50% | 7.01% | 19.17% |
| Alternatives | 6.00% | 7.08% | 8.14% |
| | | | |
| **Mean return** | **6.71%** | | |
| **Standard deviation** | **12.47%** | | |
| **CVaR 5.00 %** | **-20.34%** | | |

Source: PNYX/Ortec Finance, 2023 Annual Comprehensive Financial Report

According to our simulations, the current portfolio is expected to reach a 100% funded level by 2049 if the portfolio delivers median expected returns, as shown below in Figure 21.

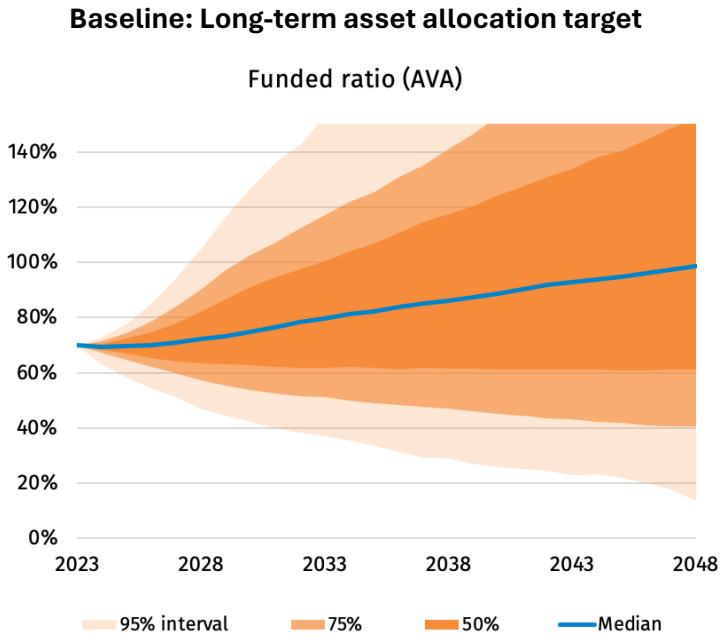



*Figure 21*

Source: PNYX/Ortec Finance

## Options for revised allocations

Table 13 shows an optimization over the next 30 years using our stochastic model. The optimization has constraints on each asset class corresponding to the bandwidths defined in the 2023 ACFR.

The optimization maintains a constant internal allocation within each asset class. For example, the relative weight of United States Equity within Global Equity remains unchanged during the optimization. The process then seeks the optimal weights by optimizing for CVaR, the tail risk

measure described above that assesses the expected return on the portfolio in the worst 5% of scenarios.

*Table 13*

| | Opt1 | Opt2 | Opt3 | Opt4 | Opt5 | Opt6 | Opt7 | Opt8 | Opt9 | Opt10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total assets** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |
| Global Equity | 48% | 48% | 48% | 48% | 48% | 48% | 48% | 48% | 48% | 59% |
| Fixed Income | 28% | 26% | 24% | 22% | 21% | 20% | 19% | 18% | 18% | 18% |
| Private Equity | 4% | 4% | 4% | 5% | 6% | 7% | 8% | 9% | 12% | 13% |
| Real Estate | 12% | 10% | 12% | 13% | 13% | 13% | 13% | 13% | 10% | 4% |
| Alternatives | 8% | 12% | 12% | 12% | 12% | 12% | 12% | 12% | 12% | 6% |
| | | | | | | | | | | |
| **Mean return** | **6.43%** | **6.49%** | **6.55%** | **6.61%** | **6.67%** | **6.73%** | **6.80%** | **6.86%** | **6.92%** | **6.98%** |
| **Standard deviation** | **10.90%** | **10.94%** | **11.12%** | **11.33%** | **11.57%** | **11.82%** | **12.07%** | **12.33%** | **12.69%** | **14.06%** |
| **CVaR 5.00 %** | **-17.58%** | **-17.64%** | **-17.97%** | **-18.33%** | **-18.71%** | **-19.10%** | **-19.49%** | **-19.89%** | **-20.34%** | **-23.04%** |

Source: PNYX/Ortec Finance

The optimization process results in 10 different portfolio weightings. We focus on two of these portfolios: the lowest-risk portfolio (Option 1) and the highest-return portfolio (Option 10).

## High return allocation

Within the limits of the current asset class, the most aggressive portfolio for the next 30 years consists of 59% Global Equity, 18% Fixed Income, 13% Private Equity, 4% Real Estate, and 6% Alternatives. The projected funded ratio under these allocations is shown in Figure 22.

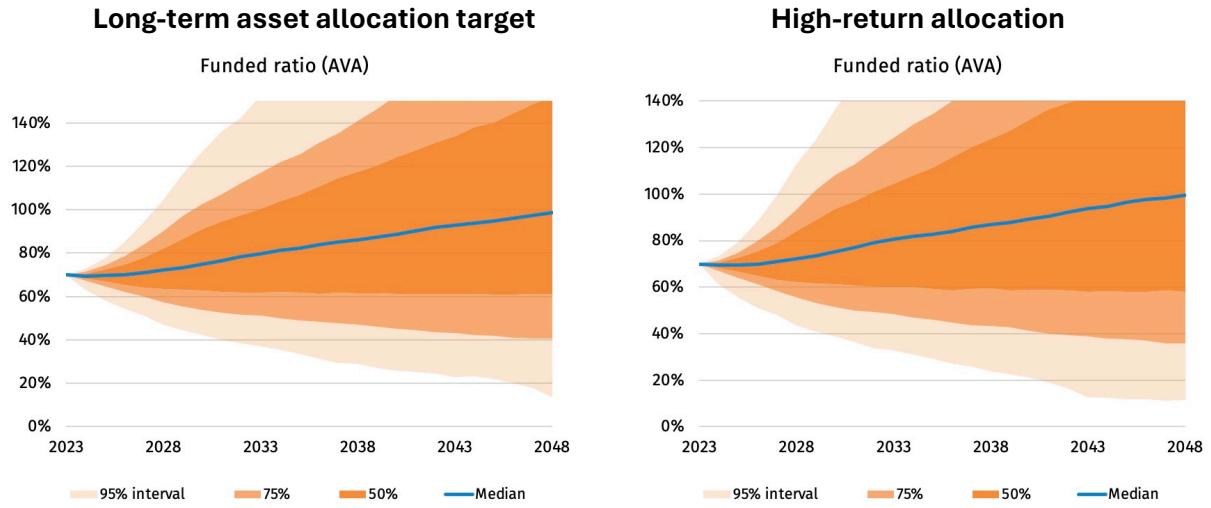



*Figure 22*

Source: PNYX/Ortec Finance

This asset allocation is expected to reach a 100% funding level by 2048. However, the different simulation paths show significant dispersion. This is evident from the increased dispersion around the median scenario. The probability of reaching a point of no return, being a funding level below 50%, increases materially.

*Table 14*

| | Expected year to reach 100% funded | Probability above 100% funded ratio by 2048 | Probability below 50% funded ratio by 2048 |
|---|---|---|---|
| Long-Term target allocation | 2049 | 49% | 18% |
| High-return allocation | 2048 | 50% | 20% |

Source: PNYX/Ortec Finance

## Low-risk allocation

The most defensive portfolio for the next 30 years consists of 48% Global Equity, 28% Fixed Income, 4% Private Equity, 12% Real Estate, and 8% Alternatives. The projections for the low-risk allocation are shown in Figure 23:

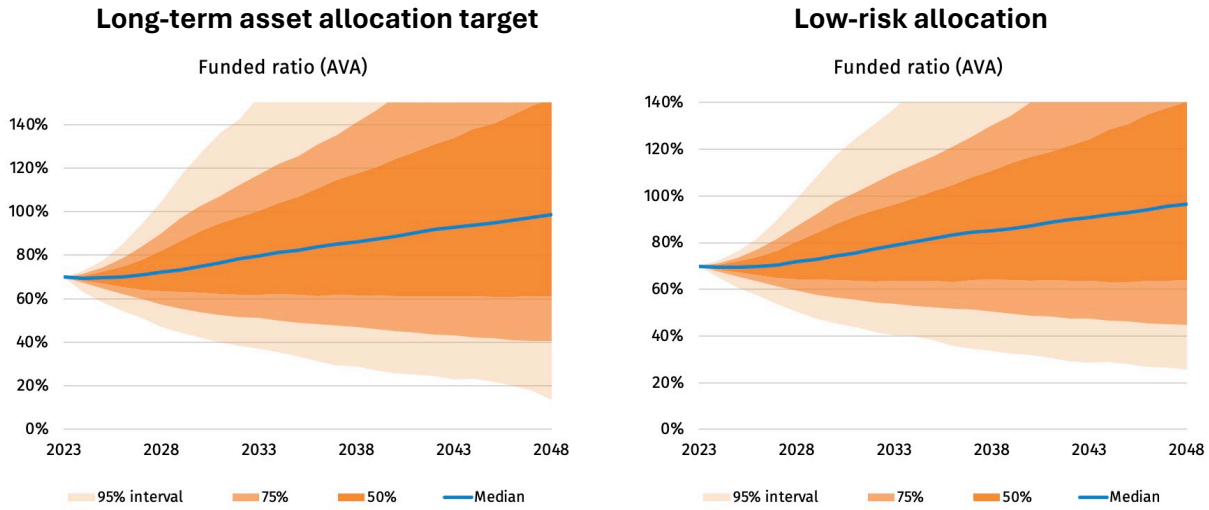



*Figure 23*

Source: PNYX/Ortec Finance

This asset allocation is the most defensive available, as indicated by the narrowed dispersion around the median. However, this comes at the cost of returns, with the timing for achieving the funding target expected to be 2051.

*Table 15*

| | Expected year to reach 100% funded | Probability above 100% funded ratio by 2048 | Probability below 50% funded ratio by 2048 |
|---|---|---|---|
| Long-Term target allocation | 2049 | 49% | 18% |
| High-return allocation | 2048 | 50% | 20% |
| Low-risk allocation | 2051 | 48% | 15% |

## Impact and further options regarding allocation

The current bands allow for limited flexibility within the current bands, given that the portfolio is 74% allocated. This restricts the impact of optimizations within the bands. Adjustments within the bands do not materially change the median time to full funding.

Despite this limitation, the results in the table above indicate that an appropriate optimization presents potential for material improvement, in particular with respect to risk. On this basis it would be worthwhile to explore the benefits of widening the bands.

Alternatively, within the existing asset classes, allocations could be made toward more alpha-generating investments, though this would mean deviating from respective benchmark compositions and their corresponding risk profiles.

Finally, the funding target could be extended, enabling a lower risk profile at the expense of a delay of some years in achieving full funding.

# Option E.2 – Lump-sum injection into the plan

This option examines the effect of a $2 billion state-funded injection into the plan, to test PERA's sensitivity to such contributions. It simulates a contribution made in 2024 with the existing asset allocation.

## Size

We have chosen an amount of $2 billion for pragmatic reasons, as the impact of $1 billion would be negligible, and we assume that a higher amount (such as $5 billion) is unlikely to be feasible in practical terms.

## Projections

The funded ratio evolution following a $2 billion injection in 2024 is shown in Figure 24, alongside the current baseline evolution. Both charts assume the existing allocation.

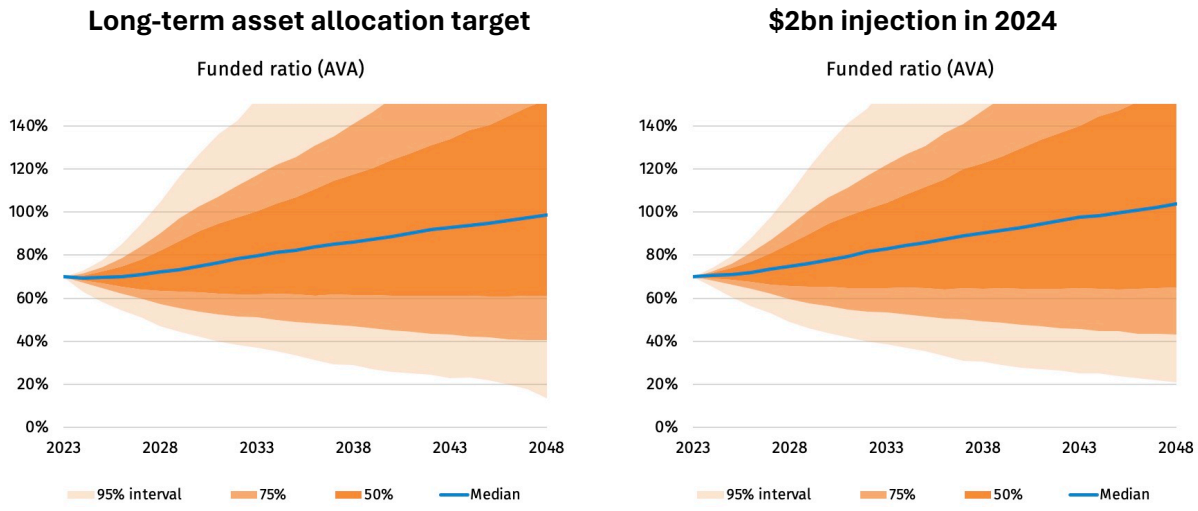



*Figure 24*

Source: PNYX/Ortec Finance

## Impact

The contribution shortens the median path to full funding by three years, from 2049 to 2046. The probability of being at or above 100% funding by 2048 increases from 49% to 53%. The probability of reaching a point of no return by 2048 (that is, a funded ratio below 50%) declines from 18% to 16%.

If the contribution was combined with the low-risk allocation described in Option E.1, we estimate that the median return path would lead to full funding by 2049, but materially lower risk of reaching a point-of-no-return situation than in the baseline to approximately 13%.

*Table 16*

| | **Expected year to reach 100% funded** | **Probability above 100% funded ratio by 2048** | **Probability below 50% funded ratio by 2048** |
|---|---|---|---|
| Long-Term target allocation | 2049 | 49% | 18% |
| High-return allocation | 2048 | 50% | 20% |
| Low-risk allocation | 2051 | 48% | 15% |
| $ 2bn injection | 2046 | 53% | 16% |

Source: PNYX/Ortec Finance

# Option E.3 – create a separate, standalone $2bn State wealth fund to meet potential shortfalls

This option presents a more innovative approach to risk management. In this option, instead of making a $2bn lump sum contribution to PERA directly, Colorado would create a new, separate State fund seeded with the same amount. The fund would manage that capital under a strategy similar to those applied by national wealth funds which maximizes returns without the constraints of the liability implications inherent to pension fund management. These approaches, when well-executed, can deliver outsized returns as well as catalytic impact in jurisdictions similar to Colorado's.

## Policy objective: mitigate downside risk

The objective of the fund would be to make capital available in 2048 in the event that PERA was not fully funded.

It would not be viewed as a compartment of PERA, and the intention would not be that PERA's overall funded status would be evaluated over time in conjunction with the new fund. Rather, the new fund would pursue a separate strategy until 2048, and effectively underwrite PERA's achievement of the 2048 funding target to the greatest extend possible. It would have a character equivalent to a national wealth fund, but at State level.

## Allocation

We can use a simplified asset allocation which replicates allocations used in other similar cases. The high-level characteristics of the allocation we use to model the performance of the new fund is shown in Table 17.

*Table 17*

| | Weights |
|---|---|
| **Total assets** | **100.00%** |
| **Listed Allocation** | **50.00%** |
| Listed Equity | 30.00% |
| Listed Defensive | 10.00% |
| Listed Debt | 10.00% |
| **Private Allocation** | **50.00%** |
| Illiquid Equity & Co-investments | 35.00% |
| Illiquid Credit | 15.00% |
| | |
| **Mean return** | **9.93%** |
| **Standard deviation** | **17.06%** |
| **CVaR 5.00 %** | **-18.38%** |

Source: PNYX

## Investment approach

The allocation above sets out a large (50%) private allocation, including a significant allocation to co-investments. This reflects an investment approach that would be biased to co-investments and club arrangements. A key advantage of setting up a state wealth fund is that it can be pre-

positioned to cooperate with other funds with similar or complimentary identities. This can be the case even if the Colorado fund is relatively small.

Access to these arrangements provides access to investment opportunities, for example through direct co-investments, that provide returns well beyond those typically achieved by pension funds.

## Performance

The chart below models the wealth fund's projected performance on the basis of the asset allocation set out above. This model is conservative and does not show the performance that could be achieved through effective co-investment and other alpha-generating techniques that are available to a national-wealth-style fund but not to a pension manager.

Figure 25 illustrates how the fund's assets would grow as a proportion of PERA's assets. From 2024 to 2048, the model shows the wealth fund's value growing from around 3% of PERA assets to approximately 13%.

In 2048, PERA's assets is expected to grow to about $167bn. The State wealth fund is expected to grow from $2bn to $21bn. This $21bn amount can be reintegrated at or before 2048 into PERA to improve the funded ratio.

**Asset value of State wealth fund value alongside PERA asset value**

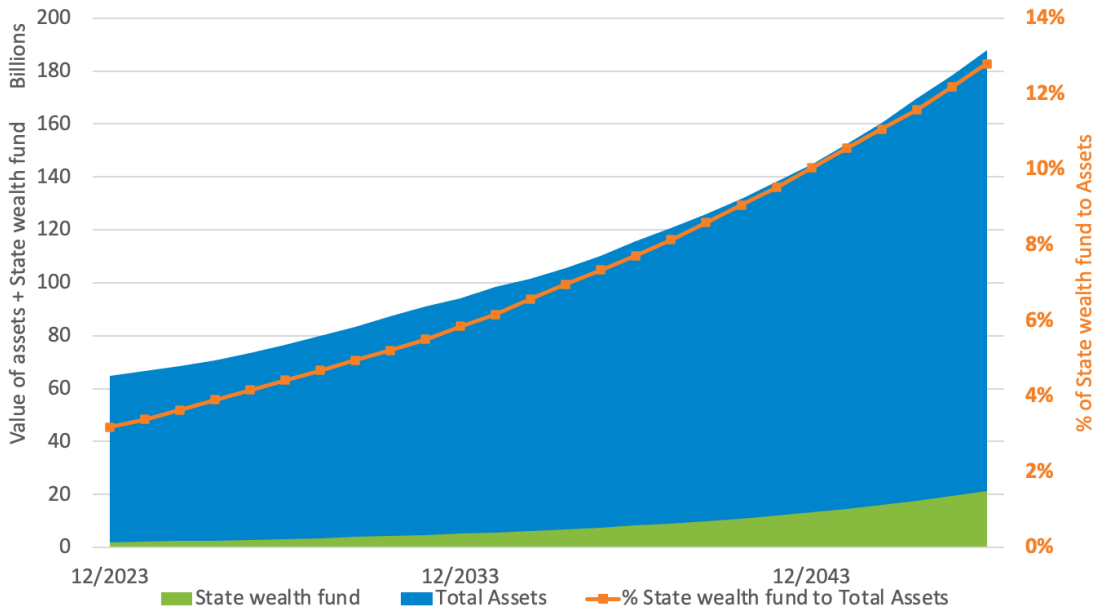



*Figure 25*

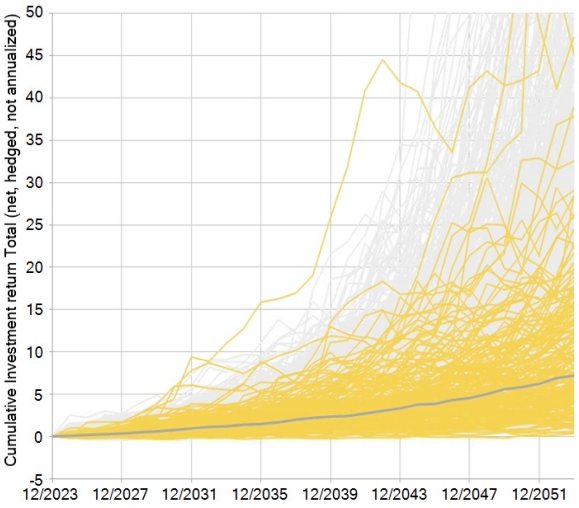
Source: PNYX/Ortec Finance

The different investment objectives of the State wealth fund allow it to make greater allocations towards long-term oriented, high-return-generating investments, with different liquidity profiles than would be possible for a pension plan accommodating liability constraints. This approach

enables the State wealth fund to grow sufficiently to cover a material portion of the unfunded liability, particularly in adverse environments.

In the chart comparison from Figure 26, we have highlighted the low growth scenario returns from the State wealth fund and the PERA allocation. Under this adverse scenario, the return of the State wealth fund is still significantly higher than that of the PERA portfolio.

**State wealth fund portfolio performance**
(low growth highlighted)




**PERA portfolio performance**
(low growth highlighted)

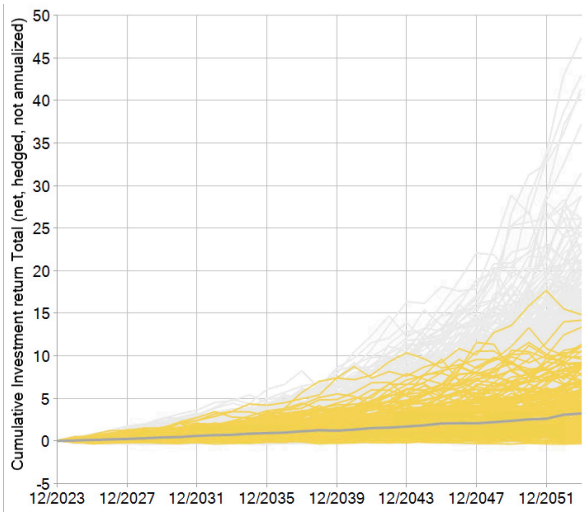



*Figure 26*

Source: PNYX/Ortec Finance

## Precedent for a State-level national wealth fund

While still uncommon at sub-state level, national wealth funds are becoming increasingly widespread. They have also been set up with the specific purpose of funding future unfunded pension liabilities, although they are not themselves pension funds. Notable examples of funds established relatively recently are Australia's Future Fund and New Zealand's NZ Super, which have grown quickly to join established funds such as those of Singapore.

Figure 27 shows a range of both Public Pension Funds (PPFs) and Sovereign Wealth Funds (SWFs) in this category together with their recent performance.

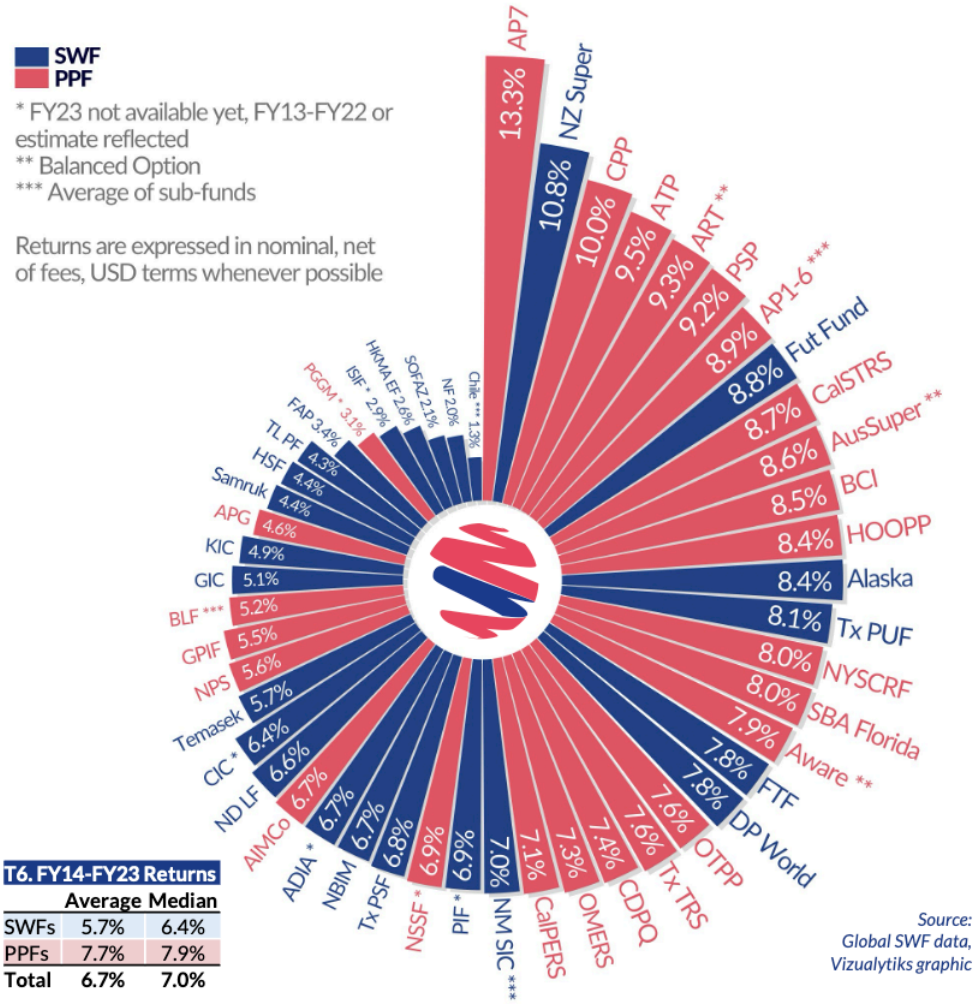



*Figure 27: Annualized Returns FY14-FY23*

As visible from Figure 27, not all such funds achieve superior performance. Critical factors are the culture, governance environment, and economic and social centrality of their home jurisdiction to regional and international markets. Colorado scores highly on these measures.

## Feasibility in Colorado

As noted above, the particular characteristics of a wealth fund's jurisdiction – its identity – are decisive for the kinds of approaches and partnerships it can pursue. Colorado has several specific characteristics that in our view make it very well positioned to establish a wealth fund that could successfully underwrite PERA while delivering catalytic impact through its investment operations.

## Governance

Colorado has a strong governance environment with, in relative terms, an effective and reliable governance system. It is not characterized by highly partisan or interest-driven politics that obtain in many jurisdictions worldwide.

## Values

The State's history and geography appears to have resulted in a range of reasonably widely held values, including an appreciation for nature and outdoor activities, entrepreneurial spirit, independence and self-reliance, and innovation and progress.

## Economy and society

The State has very high economic and social connectedness across markets and industries. Its high GDP and innovation-heavy economy (electronics, defense, tourism, certain government functions) makes it an attractive potential investment destination for peer co-investors who can access trusted local opportunities through a state wealth fund.

Those same attributes position it well to be able to obtain superior returns outside its borders, and to select and structure opportunities presented by peers to strategic effect. In particular Colorado's strong financial center and numerous leading corporates can provide the pool of deep (though not necessarily numerous) local talent that is necessary for effective financial decision-making, as well as active governance engagement with investees.

## Aggregate impact

Although the strategy should not be viewed in the aggregate (since this would negatively affect the wealth fund's mandate and ability to achieve potential returns), the analysis can be done for mathematical purposes.

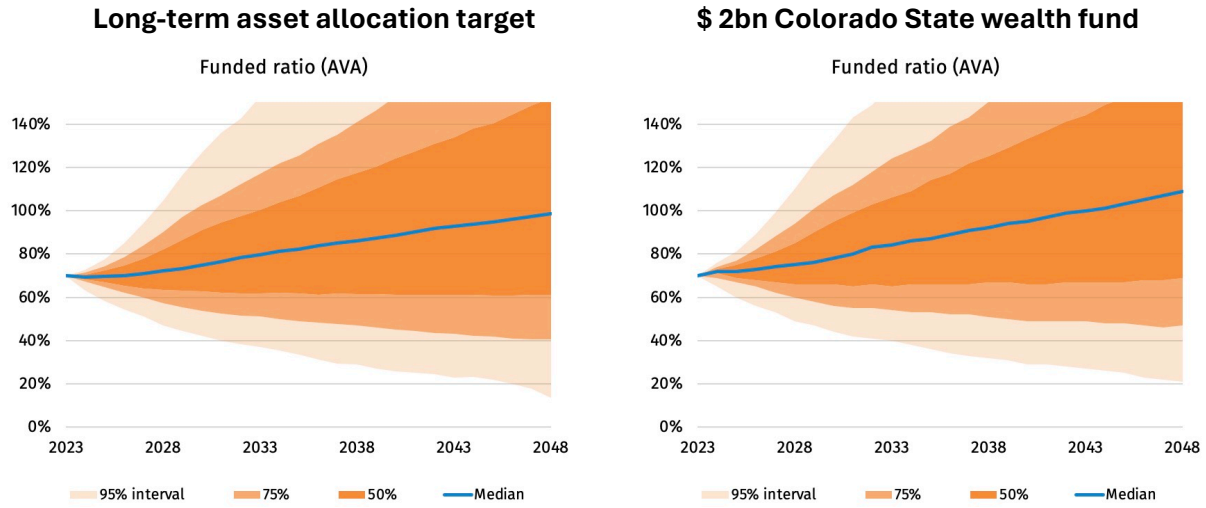



*Figure 28*

Source: PNYX/Ortec Finance

If aggregated with the wealth fund, PERA would be expected to reach full funding by 2043, with a funded ration of below 50% having only a14% likelihood, down from 18% in the base case. The comparative figures are shown in Table 18.

*Table 18*

| | **Expected year to reach 100% funded** | **Probability above 100% funded ratio by 2048** | **Probability below 50% funded ratio by 2048** |
|---|---|---|---|
| Long-Term target allocation | 2049 | 49% | 18% |
| High-return allocation | 2048 | 50% | 20% |
| Low-risk allocation | 2051 | 48% | 15% |
| $ 2bn injection | 2046 | 53% | 16% |
| $ 2bn Colorado wealth fund | 2043 | 56% | 14% |

Source: PNYX/Ortec Finance

# Option E.4 – Increase contributions

This option examines the impact of increasing contributions by 1% of payroll, with that increase applied to the cash flows over all years to 2048 (no assumption is made about whether such a contribution is by employee- or employer-funded).

## Projections

The projection involves a re-run of the funded ratio model referred to in Part A, with a horizontal adjustment applied to contributions. The results are shown in Table 19.

*Table 19*

| | **Projected years until 100% funded (PNYX assumptions)** | **+1% contribution** |
|---|---|---|
| State Division | 25 | 23 |
| School Division | 32 | 28 |
| Local Government Division | 13 | 11 |
| Judicial Division | 8 | 8 |
| DPS Division | 8 | 8 |
| **Total** | **26** | **23** |

Source: PNYX/Ortec Finance

The 1% contribution equates to an aggregate non-discounted value of $4.45 billion. Applying a discount rate of 7.25%, the present value of this amount is $1.81 billion. This significant discount is due to the heavily reduced present value of future contributions, which are based on higher future payroll. The 7.25% does not appear to be the most appropriate discount rate.

## Impact

The impact is material on an overall basis, reducing the median funding time by three years. In conjunction with other options set out in this Part, there may be value in exploring an adjustment in contributions if considered more broadly feasible on a stakeholder basis.

# Part F
# Recommendations

## Non-economic assumptions

1. A new Actuarial Experience Report is due for publication by Segal Group in 2024, presumably in the coming months. The report should draw only on Segal Group's eight years of experience with PERA and not give any weight to the methodologies or assumptions applied previously by the Plan's previous actuary, Cavanaugh MacDonald. This is likely to result in revised assumptions aligned with those of the GRS report. Particular attention could be directed toward employee turnover, salary increase, and new entrant assumptions.

## Economic assumptions

2. Assuming no change to its target asset allocation, PERA's return assumption should be revised downward. Our modeling projects a portfolio rate of return of 6.71%, compared with the currently assumed rate of 7.25%.
3. A review of the portfolio's economic modeling approach should be undertaken, including a revision in methodology to incorporate correlations and asymmetries that can deliver more representative projections.
4. The return assumption should be considered against the backdrop of the wide dispersion in projected portfolio performance, and risk measures such as tail risk should be used to develop a more representative risk picture.

## Policy options

5. Given PERA's projected funding path, options for improving its position should be considered. The target allocation bands should be widened, and the actual allocation should be optimized within them, based on a decision on whether to prioritize return or risk management.
6. As a policy matter decision makers should consider the benefits of a lump sum contribution. This would be significantly more impactful than a contribution to the plan in the same amount, both as a risk mitigant for PERA and for the people of the State of Colorado.

# Annexes

**Annex I** – Signal light comparison by PERA division

**Annex II** - PNYX/Ortec Finance modeling approach

**Annex III** - Effect of cash flow position

# Annex I - Signal light comparison by PERA division

Our modeling applies our economic expectations to the contribution and benefit cash flows that, using PERA's current asset allocation. Aside from layering portfolio performance over the cash flows, the model also applies inflation expectations to both legs of the cash flows in each simulation. The resulting simulations are set out below for each division.

The figures show a higher probability of achieving a 100% funded ratio by 2048 than the Segal projections. As noted above, the Segal projections would not have incorporated the good market return of 2023, whereas the PNYX figures do, and this may account for the discrepancy.

The figures are set out on the following pages.

## State division

**Long-Term View Signal Lights for State Division**
**Stochastic Modeling of Investment Return – Open Group Projection Basis**
**Assumes Active Membership Grows by 0.25% per Year**

| Status | Definition | Number of Scenarios Meeting [1] | Probability of Meeting | |
|---|---|---|---|---|
| **Dark Green** | 100% Funded by 2041 (30 years from 2011) | 1,583 | 32% | 42% |
| **Green** | 100% funded by 2048 (30 years from 2018) | 520 | 10% | |
| **Light Yellow** | **100% funded by 2058 (40 years from 2018)** | **538** | **11%** | 41% |
| **Yellow** | 100% funded by 2068 (50 years from 2018) | 382 | 8% | |
| **Orange** | Solvent but longer than 50 years to reach 100% funded | 1,111 | 22% | |
| **Red** | Insolvent after 2043 (after 20 years) | 630 | 12% | 17% |
| **Dark Red** | Insolvent by 2043 (within 20 years) | 236 | 5% | |

[1] Based on 5,000 simulations

Source: Segal 2022 Signal Light Report

| Status | Definition | Number of Scenarios Meeting | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% funded by 2041 (30 years from 2011) | 820 | 41% | 50% |
| Green | 100% funded by 2048 (30 years from 2018) | 179 | 9% | |
| Light Yellow | 100% funded by 2058 (40 years from 2018) | 154 | 8% | 33% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 35 | 2% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 465 | 23% | |
| Red | Insolvent after 2043 (after 20 years) | 29 | 1% | 17% |
| Dark Red | Insolvent by 2043 (within 20 years) | 318 | 16% | |

Source: PNYX/Ortec Finance

## School division

**Long-Term View Signal Light Results for School Division**
**Stochastic Modeling of Investment Return – Open Group Projection Basis**
**Assumes Active Membership Grows by 1.00% per Year**

| Status | Definition | Number of Scenarios Meeting [1] | Probability of Meeting | |
|---|---|---|---|---|
| **Dark Green** | 100% Funded by 2041 (30 years from 2011) | 1,519 | 30% | 40% |
| **Green** | 100% funded by 2048 (30 years from 2018) | 494 | 10% | |
| **Light Yellow** | 100% funded by 2058 (40 years from 2018) | 512 | 10% | 43% |
| **Yellow** | **100% funded by 2068 (50 years from 2018)** | **386** | **8%** | |
| **Orange** | Solvent but longer than 50 years to reach 100% funded | 1,244 | 25% | |
| **Red** | Insolvent after 2043 (after 20 years) | 722 | 14% | 17% |
| **Dark Red** | Insolvent by 2043 (within 20 years) | 123 | 3% | |

[1] Based on 5,000 simulations

Source: Segal 2022 Signal Light Report

| Status | Definition | Number of Scenarios Meeting | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% funded by 2041 (30 years from 2011) | 742 | 37% | 44% |
| Green | 100% funded by 2048 (30 years from 2018) | 145 | 7% | |
| Light Yellow | 100% funded by 2058 (40 years from 2018) | 163 | 8% | 33% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 28 | 1% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 468 | 23% | |
| Red | Insolvent after 2043 (after 20 years) | 70 | 4% | 23% |
| Dark Red | Insolvent by 2043 (within 20 years) | 384 | 19% | |

Source: PNYX/Ortec Finance

## Local Government division

**Long-Term View Signal Light Results for Local Government Division**
**Stochastic Modeling of Investment Return – Open Group Projection Basis**
**Assumes Active Membership Grows by 1.00% per Year**

| Status | Definition | Number of Scenarios Meeting [1] | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% Funded by 2041 (30 years from 2011) | 2,150 | 43% | 49% |
| Green | 100% funded by 2048 (30 years from 2018) | 312 | 6% | |
| **Light Yellow** | **100% funded by 2058 (40 years from 2018)** | **265** | **5%** | 26% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 248 | 5% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 810 | 16% | |
| Red | Insolvent after 2043 (after 20 years) | 1,029 | 21% | 25% |
| Dark Red | Insolvent by 2043 (within 20 years) | 186 | 4% | |

[1] Based on 5,000 simulations

Source: Segal 2022 Signal Light Report

| Status | Definition | Number of Scenarios Meeting | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% funded by 2041 (30 years from 2011) | 1037 | 52% | 53% |
| Green | 100% funded by 2048 (30 years from 2018) | 25 | 1% | |
| Light Yellow | 100% funded by 2058 (40 years from 2018) | 5 | 0% | 20% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 9 | 0% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 387 | 19% | |
| Red | Insolvent after 2043 (after 20 years) | 217 | 11% | 27% |
| Dark Red | Insolvent by 2043 (within 20 years) | 320 | 16% | |

Source: PNYX/Ortec Finance

## Judicial division

**Long-Term View Signal Light Results for Judicial Division**
**Stochastic Modeling of Investment Return – Open Group Projection Basis**
**Assumes Active Membership Grows by 0.25% per Year**

| Status | Definition | Number of Scenarios Meeting [1] | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% Funded by 2041 (30 years from 2011) | 2,901 | 58% | 66% |
| Green | 100% funded by 2048 (30 years from 2018) | 408 | 8% | |
| Light Yellow | 100% funded by 2058 (40 years from 2018) | 414 | 8% | 29% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 281 | 6% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 740 | 15% | |
| Red | Insolvent after 2043 (after 20 years) | 248 | 5% | 5% |
| Dark Red | Insolvent by 2043 (within 20 years) | 8 | 0% | |

[1] Based on 5,000 simulations

Source: Segal 2022 Signal Light Report

| Status | Definition | Number of Scenarios Meeting | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% funded by 2041 (30 years from 2011) | 1037 | 52% | 53% |
| Green | 100% funded by 2048 (30 years from 2018) | 25 | 1% | |
| Light Yellow | 100% funded by 2058 (40 years from 2018) | 5 | 0% | 20% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 9 | 0% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 387 | 19% | |
| Red | Insolvent after 2043 (after 20 years) | 217 | 11% | 27% |
| Dark Red | Insolvent by 2043 (within 20 years) | 320 | 16% | |

Source: PNYX/Ortec Finance

## DPS division

**Long-Term View Signal Light Results for Denver Public Schools Division**
**Stochastic Modeling of Investment Return – Open Group Projection Basis**
**Assumes Active Membership Grows by 1.00% per Year**

| Status | Definition | Number of Scenarios Meeting [1] | Probability of Meeting | |
|---|---|---|---|---|
| **Dark Green** | **100% Funded by 2041 (30 years from 2011)** | **3,101** | **62%** | 74% |
| **Green** | 100% funded by 2048 (30 years from 2018) | 575 | 12% | |
| **Light Yellow** | 100% funded by 2058 (40 years from 2018) | 567 | 11% | 26% |
| **Yellow** | 100% funded by 2068 (50 years from 2018) | 310 | 6% | |
| **Orange** | Solvent but longer than 50 years to reach 100% funded | 447 | 9% | |
| **Red** | Insolvent after 2043 (after 20 years) | 0 | 0% | 0% |
| **Dark Red** | Insolvent by 2043 (within 20 years) | 0 | 0% | |

[1] Based on 5,000 simulations

Source: Segal 2022 Signal Light Report

| Status | Definition | Number of Scenarios Meeting | Probability of Meeting | |
|---|---|---|---|---|
| Dark Green | 100% funded by 2041 (30 years from 2011) | 1320 | 66% | 71% |
| Green | 100% funded by 2048 (30 years from 2018) | 106 | 5% | |
| Light Yellow | 100% funded by 2058 (40 years from 2018) | 91 | 5% | 19% |
| Yellow | 100% funded by 2068 (50 years from 2018) | 54 | 3% | |
| Orange | Solvent but longer than 50 years to reach 100% funded | 240 | 12% | |
| Red | Insolvent after 2043 (after 20 years) | 73 | 4% | 9% |
| Dark Red | Insolvent by 2043 (within 20 years) | 116 | 6% | |

Source: PNYX/Ortec Finance

# Annex II – PNYX/Ortec Finance modeling approach

This annex sets out features of the PNYX/Ortec Finance modeling approach.

For context, differences between the Segal/Aon Hewitt and PNYX/Ortec Finance modeling approaches are summarized below.

| | **Segal/Aon Hewitt** | **PNYX/Ortec Finance** |
|---|---|---|
| **Correlation** | Relatively simple spreadsheet model, without macroeconomic correlations | Economics-driven fundamentals model, with asset classes intercorrelated among themselves and with macroeconomic factors |
| **Asset return distribution** | Normally distributed, assuming symmetric returns | Negative skew with fat tails, modeling asymmetric returns and extreme events |
| **Time horizon** | Static assumptions across all time horizons | Different correlation tables for short-, medium- and long-term horizons, including business cycles of different tenors |
| **Macro factors** | Deterministic inflation on liability side | Stochastic macro factors on both liability and asset sides |

# Selected elements of the Ortec Finance approach

Aspects of the Ortec Finance modeling system, and factors which it includes, are set out in the following diagrams.

- Yield curve, spread curve, excess return scenarios, and also rating transition probabilities are combined with (benchmark or client specific) maturity (duration) and rating profiles to obtain fixed income return scenarios
- The same yield curve scenarios can be used for consistent valuations of liabilities

## Equities, Commodities, Real Estate, Hedge Funds and other alternatives

- Based on total return scenarios

## Fixed Income Instruments

- Valuation based on term structures scenarios
- Instruments: Bullets, linear redeemable bonds, zero coupons, index-linked, nominal and index-linked swaps, swaptions, etc.
- Credit Bonds: Spread and excess return scenarios, also rating migrations for AAA...CCC ratings

## Other

- Put/call options
- FX forwards
- Private Assets

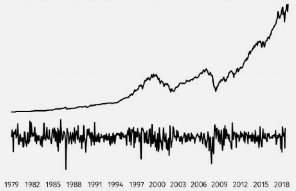
- GDP, Unemployment, CPI, Wages
- Equity Total Return Index, Dividend Yields
- Residential, Offices and Retail prices, Indirect Real Estate
- Government, Swap and Break Even Inflation term structures
- Private Equity, Infrastructure, Hedge Funds, Commodities
- Credit spreads
- Exchange rates
- Implied Volatilities for Options
- ESG
  - ESG leaders & Climate Paris Aligned Equities
  - Corporate Green bonds & ESG Fixed Income

## Across countries and regions

| | | | |
|---|---|---|---|
| US | UK | Canada | Europe |
| Netherlands | Norway | Denmark | Finland |
| Switzerland | Sweden | World | Australia |
| Brazil | Japan | China | Singapore |
| South Korea | India | Thailand | New Zealand |
| Russia | Malaysia | Taiwan | Indonesia |

*Note: the **mapping** of assets is performed by Ortec Finance consultants, as part of the implementation.*

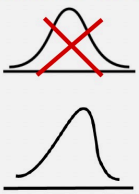
## Economic and financial market conditions




Today's state of financial markets drive short-term return expectations:

- Bond yields
- Bull / bear markets
- Volatility
- ...

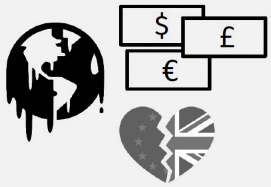
## Realistic models and stylized facts



Projections of risk and return take into account well-known, observable patterns in historical data, so-called stylized facts:

- Risk and return vary over time (e.g. yields)
- Cyclicality
- Tail risk
- Non-normality
- Yield curves drive bond returns
- ...

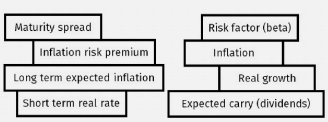
## Relevant info not captured by data ('views')




Some 'events' are not (yet) captured by historical data but drive risk and return:

- Monetary policy
- 'Brexit'
- Climate change
- ...

## Long-term expectations



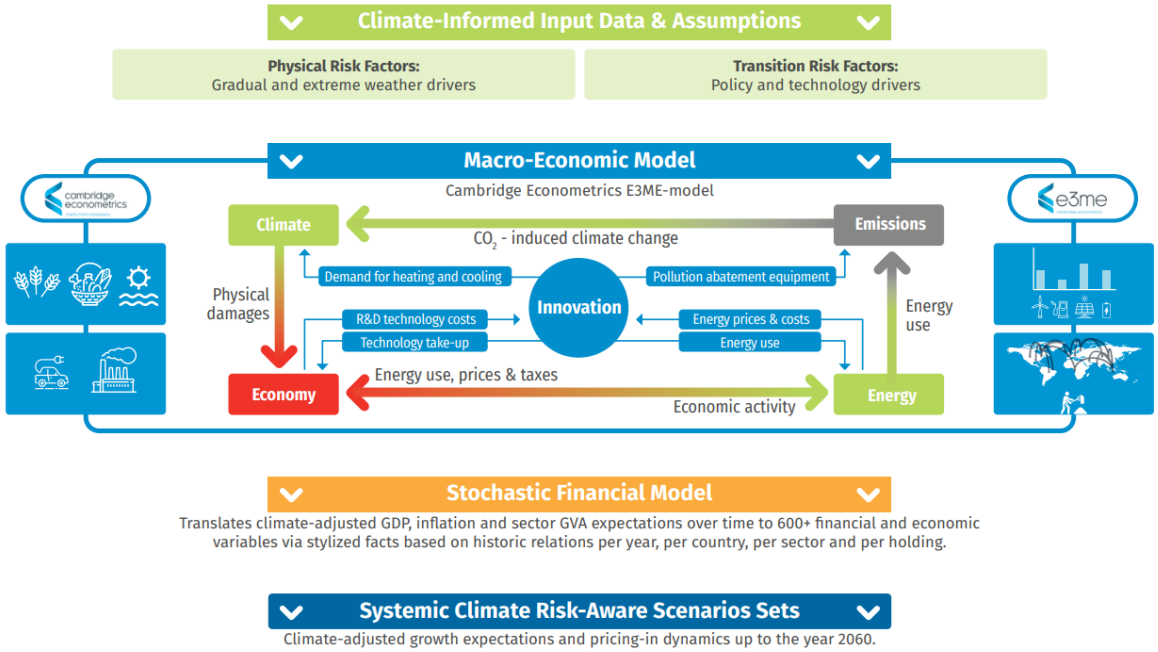

Projections converge to a steady state or equilibrium. These assumptions are based on a building block approach.

Source: Ortec Finance

## Scenarios

The system allows for a unique scenario construction approach. The approach ensures that the scenarios generated are closely aligned with real-world conditions, making them effective and reliable for forward-looking projections.

In particular, sophisticated climate-based scenarios can also be simulated using the framework, based on selected climate paths. Those paths are described in the diagrams below.




| Net-Zero | Net-Zero Financial Crisis | Limited Action | High Warming |
|---|---|---|---|
| ▪ **Early and smooth** transition<br>▪ **Market pricing-in** dynamics occur smoothed out in the first 3 years<br>▪ **Locked-in** physical impacts | ▪ Sudden divestments in 2025 to align portfolios to the Paris Agreement goals have **disruptive effects on financial markets** with sudden repricing followed by stranded assets and a sentiment shock<br>▪ **Locked-in** physical impacts | ▪ Policymakers implemented **limited NDCs** and **fall short of meeting the Paris Agreement goals**.<br>▪ **High** physical impacts<br>▪ **Markets price in physical risks** of the coming 40 years over 2026-2030, and risks of 40-80 years over 2036-2040 | ▪ The world **fails to meet the Paris Agreement goals** and global warming reaches 4.3°C above pre-industrial levels by 2100<br>▪ **Very severe** physical impacts<br>▪ **Markets price in physical risks** of the coming 40 years over 2026-2030, and risks of 40-80 years over 2036-2040. |
| Average temperature increase by 2100 of **1.5°C**<br>~ 'very low emissions' IPCC scenario:<br>**SSP1-RCP1.9**<br>~50% probability of limiting warming to 1.5°C | Average temperature increase by 2100 of **1.5°C**<br>~ 'very low emissions' IPCC scenario:<br>**SSP1-RCP1.9**<br>~50% probability of limiting warming to 1.5°C | Average temperature increase by 2100 of **2.8°C**<br>~ 'intermediate emissions' IPCC scenario:<br>**SSP2-RCP4.5**<br>*Very likely* 2.1°C – 3.5°C warming by 2100 | Average temperature increase by 2100 of **4.2°C**<br>~ 'high emissions' IPCC scenario:<br>**SSP3-RCP7.0**<br>*Very likely* 3.4°C – 5.6°C warming by 2100 |
| Tests exposure to the risks/ opportunities from the systemic drivers of an orderly transition and locked-in physical risk | Shows the resilience of portfolios to sudden repricing, triggering market dislocation centered on high-emitting stocks | Highlights how scaled-down transition policy leads to larger physical risk and material transition risk for portfolios | The main focus of this pathway is physical risk, results show the exposure to plausible, severe climate change impacts |

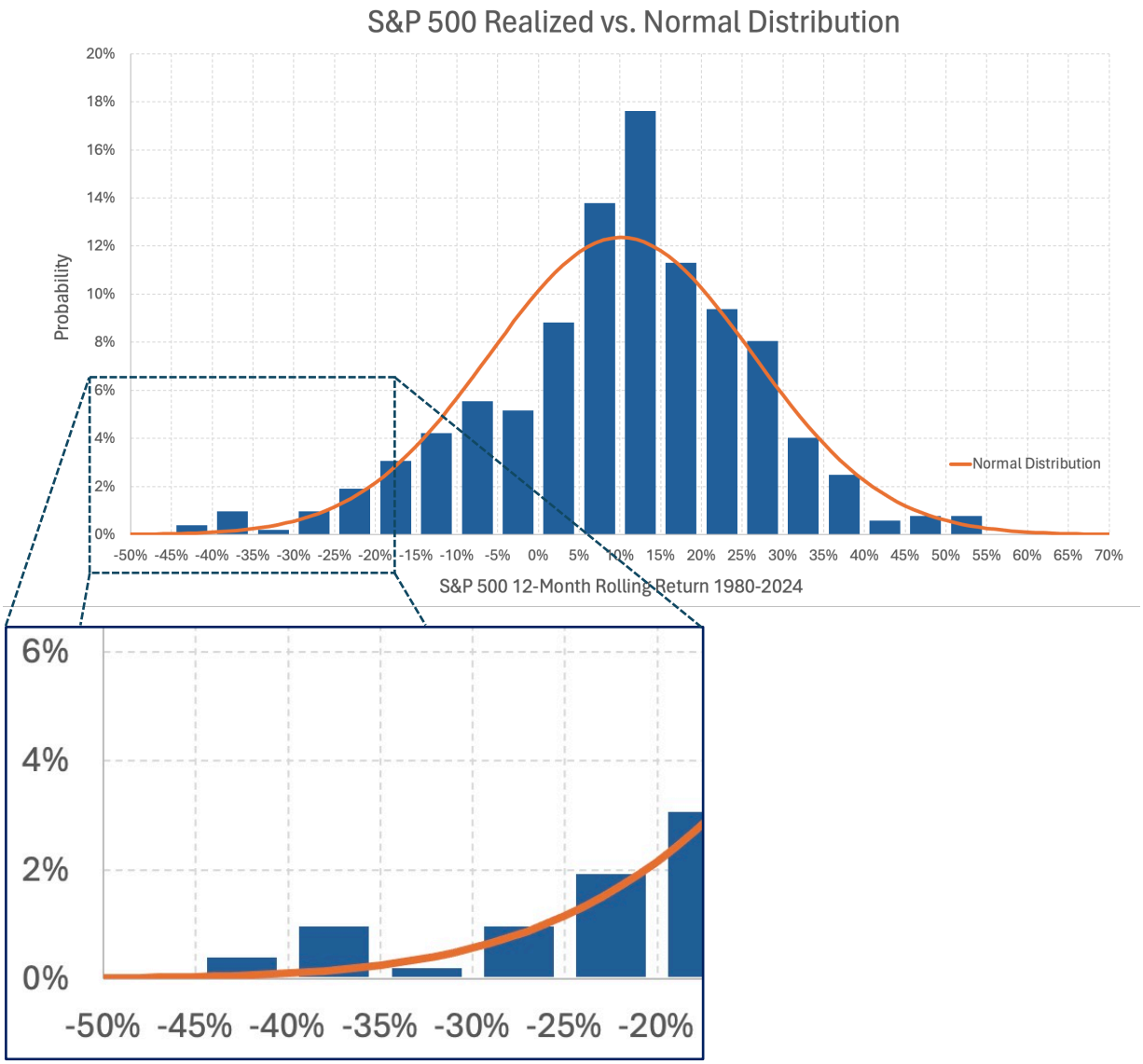
Source: Ortec Finance

## Stylized facts to increase realism

Ortec Finance has researched various market behaviors known as stylized facts. There stylized facts are integrated into scenario generation process to produce realistic scenarios. One of the most important stylized facts is the non-normal distribution of asset returns.

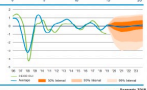
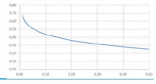
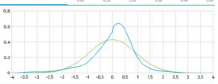
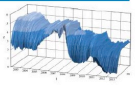
Financial asset returns typically exhibit a non-normal distribution. This phenomenon, also referred to as a "stylized fact," is illustrated in the following return distribution chart. The blue bars represent the probability distribution of realized S&P 500 rolling 12-month returns, while the orange bell-shaped curve represents the normal distribution derived from the statistics (mean and standard deviation) of the observed data.

Other important market assumptions are integrated as stylized facts.



The normal distribution is known to underestimate return probabilities at both ends. However, this underestimation is more pronounced in the left tail, which represents the most negative returns. This is particularly concerning because it means the normal distribution significantly underestimates the probability of severe losses.

Further examples of stylized facts implemented within scenario construction are shown below.

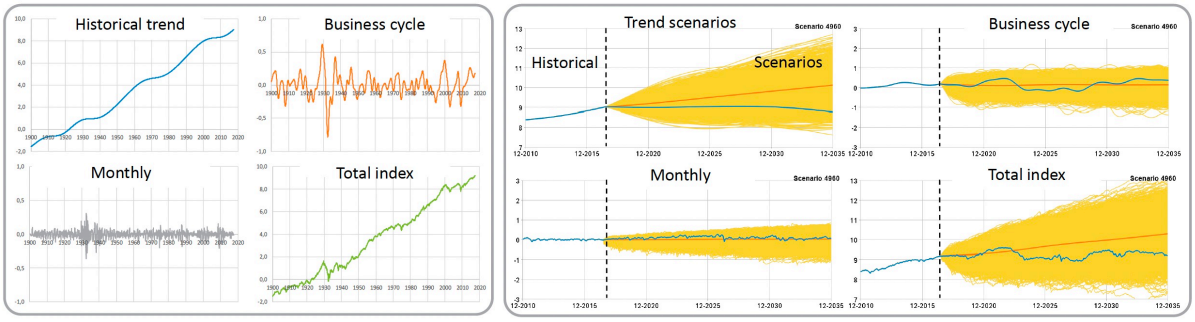
| | | |
|---|---|---|
| Term structure of risk and return | Risk and return vary with the investment horizon, e.g. equity – inflation correlation higher on longer horizons |  |
| Business cycles | Medium term fluctuations inherent to economies and markets, e.g. equities leading on real economy, prices lagging |  |
| Time varying volatility | E.g. low volatility in years preceding the financial crisis |  |
| Tail risk | Correlations increase in times of crisis (less diversification) |  |
| Non-normal distributions | Skewed and fat-tailed distributions |  |
| Yield curves | E.g. parallel and tilt movements across maturities |  |

Source: Ortec Finance

## Asset class simulation

The final projection of each asset class incorporates stylized facts to produce realistic simulations as well as the combination of projections over three different time horizons.

### Example: US equities total return index in USD (log scale)



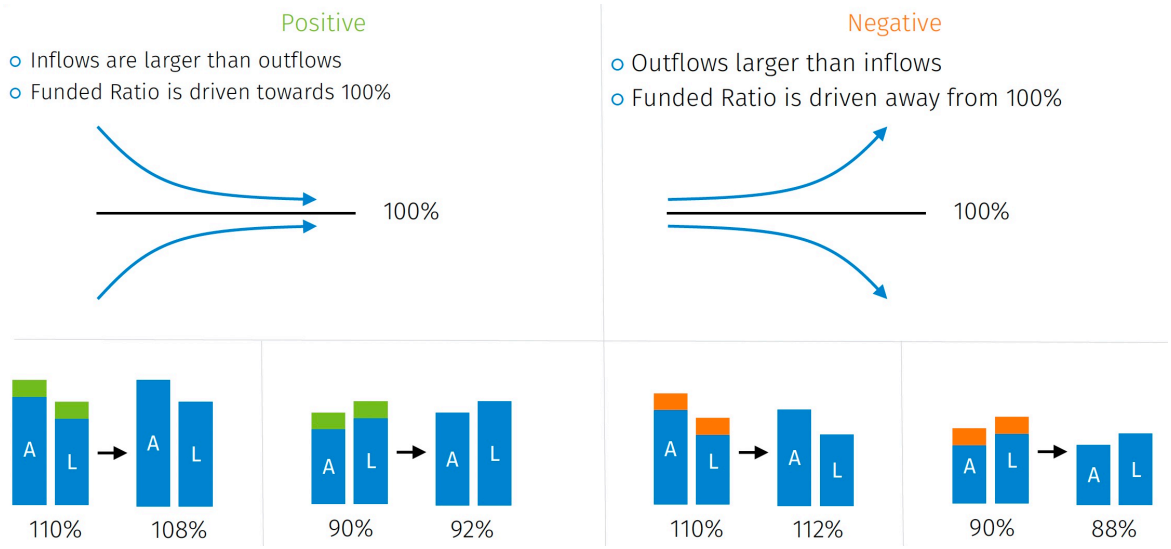

- Better understanding and capturing of long-, medium and short-term risk and return
- To support better (SAA and DAA) asset-allocation decisions
- E.g. Campbell and Viceira (2002), Chaudhuri and Lo (2016)

# Annex III - Effect of cash flow position

For plans which have a positive cash flow position, their funded ratio will converge toward 100% whether they are in an overfunded or underfunded state.

Conversely, plans which have negative cash flow will have their funded ratio driven away from 100%, again whether they are over or underfunded.

**Net Cash Flow effect on Funded Ratio**




Source: Ortec Finance

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