



Eric Hughes, Strategist Product Manager, PSNM IRP Stakeholder Meeting, November 10, 2016

Strategist[®] Strategic Planning Solution

Agenda

- ABB Enterprise Software Overview
- Strategist Overview
- Strategist Model Details
- Resource Planning - Risk Analysis

ABB Enterprise Software, Inc.

Overview

ABB EPM Overview

ABB corporate overview

~145,000 
employees

 **\$ 35.5**
billion
In revenue
(2015)

Present
in
>100 
countries

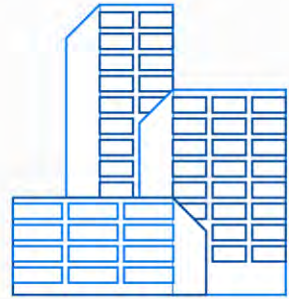
Formed
in
1988 
merger of Swiss (BBC, 1891)
and Swedish (ASEA, 1883)
engineering companies

ABB EPM Overview

ABB corporate overview

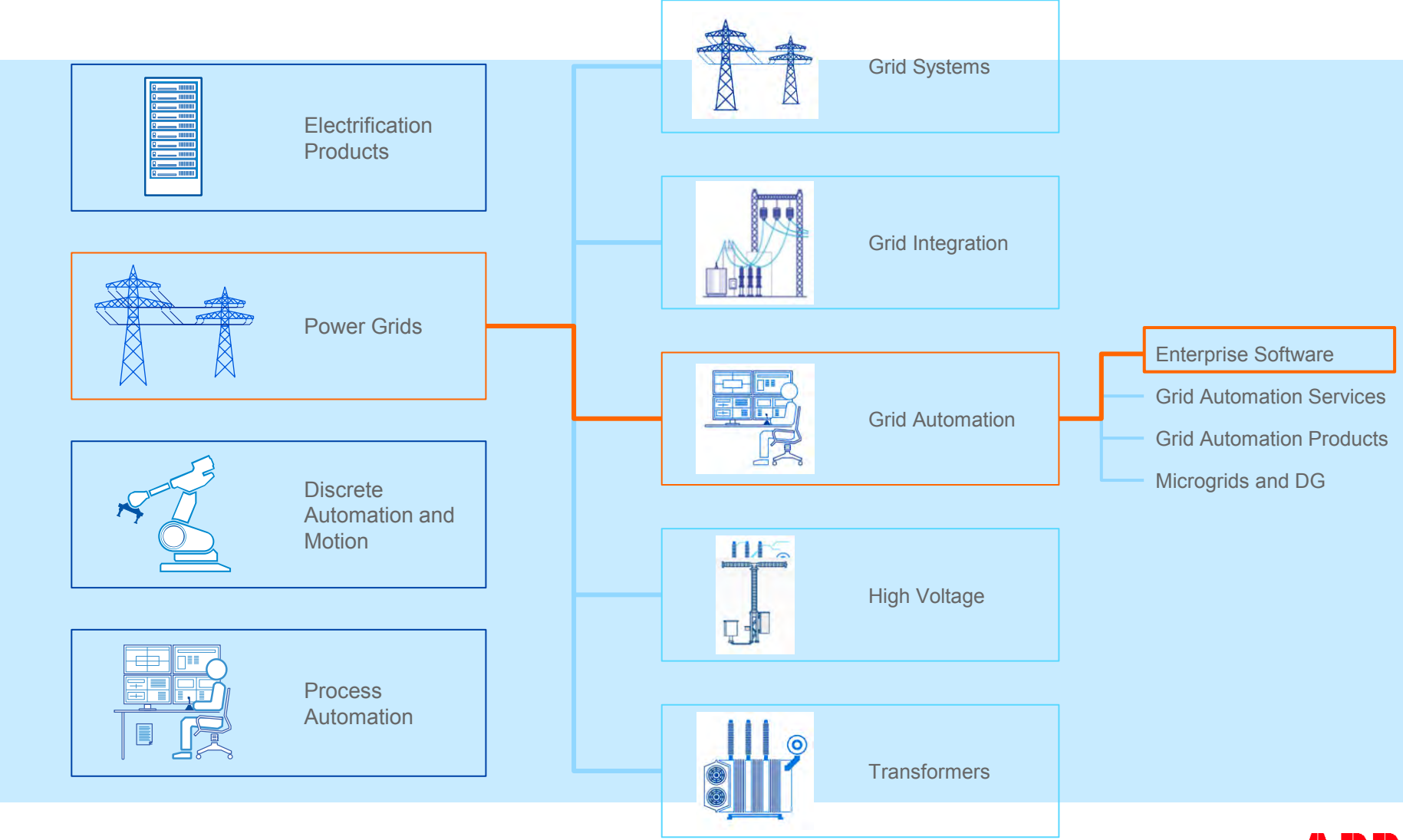


ABB EPM Background

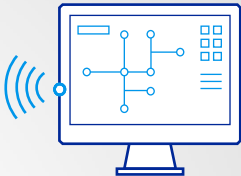
ABB EPM at a glance

200+



employees

1975



introduced first
commercial optimization
software for utilities

~1.4 TW



managed
generating
capacity

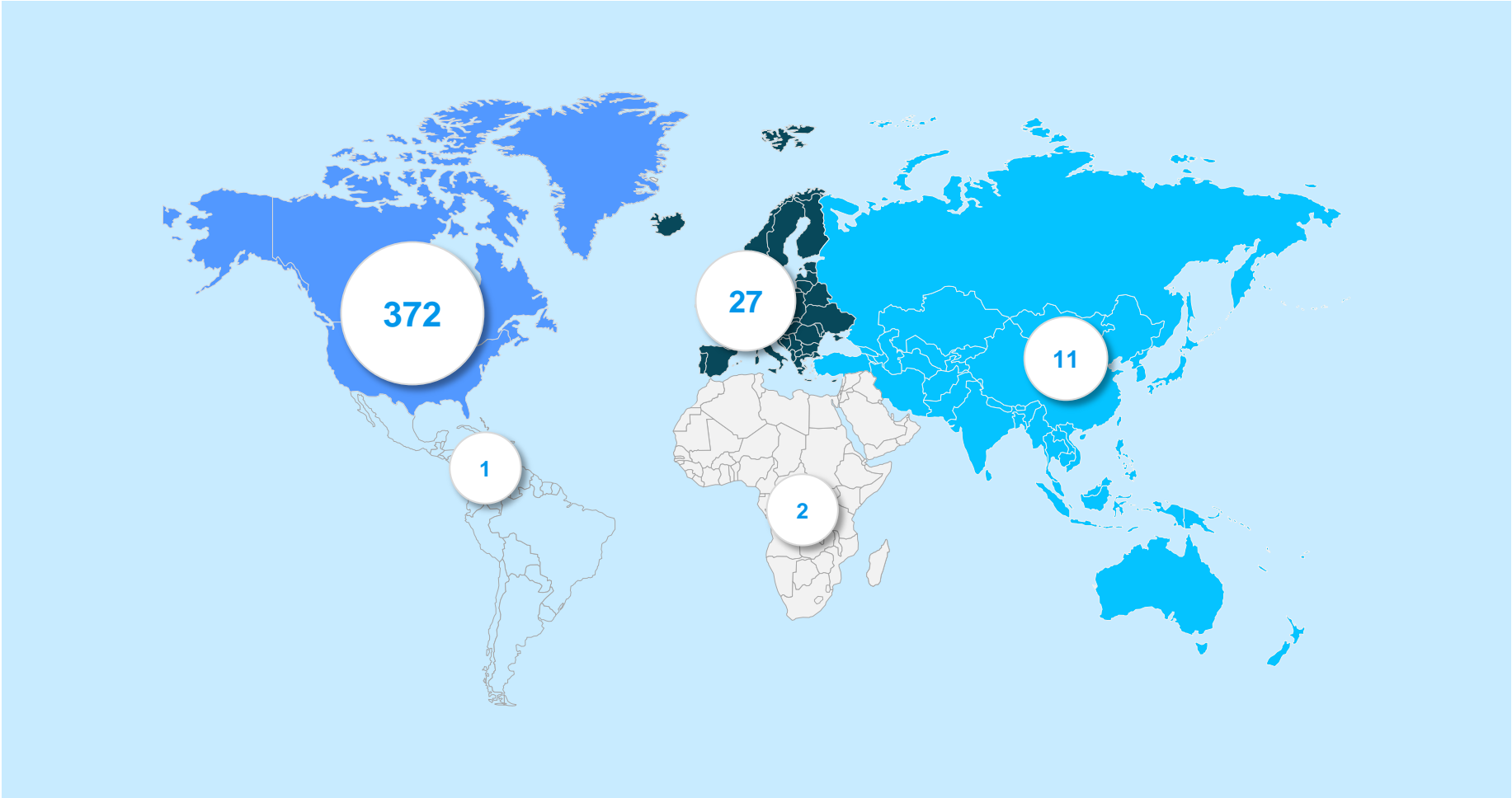
\$5B+



investment
decisions supported

ABB EPM Background

Global customer footprint



Strategist Overview

Overview

Topics

- What is Strategist?
- Who uses it?
- Access to Strategist
- What is Strategist suited/not suited for?

Strategist

What is it?

- Strategic planning software application for electric utility companies
- First introduced in 1980 as PROSCREEN II – New interface and renamed Strategist in 2000
- Long time horizons – 20 to 30 years are typical
- Probabilistic production cost simulation model
- Optimizes future resource additions
 - Uses a proprietary Dynamic Programming optimization algorithm
 - Objective function: minimize capital and operating costs
 - Generates multiple plans and ranks them by objective function value
- Optimal solution is subject to multiple constraints including:
 - Reserve margins
 - Emissions limits
 - RPS requirements
 - Availability constraints on individual options

Strategist

What is it?

- Future resource decisions can include:
 - Supply-side and Demand-side
 - Build new resources
 - Buy existing resources
 - Refurbish/Repower/Mothball/Retire plants
 - Environmental compliance
 - Renewable portfolio standards
- Primary uses:
 - Integrated Resource Planning (IRP) Analysis
 - Request for Proposal (RFP) Evaluations

Strategist

Who uses it?

- Current active licenses include:
 - 34 utility companies – IOUs, coops, & municipals
 - 4 regulatory bodies
 - 6 consulting companies

Strategist

Access to the program & documentation

- The program is only available to entities that have a license agreement with ABB Enterprise Software
 - Entities that license the software also have access to the user documentation.
- Access to the user documentation is available for entities without a software license that enter into a Non-Disclosure Agreement (NDA) with ABB Enterprise Software.

Strategist

What is the model suited/not suited for?

- Best usage:
 - Long term studies (20+ years)
 - Multiple resource selection decision options
 - Lower level of detail required for production cost simulation
 - Resource selection decisions need to be based on long term economics
- Do not use Strategist for:
 - Short term analysis
 - Studies requiring high level of operational detail
 - Not an hourly dispatch model
 - Does not include ramp rates or start costs
 - Not appropriate for fuel and O&M budgeting analysis

Strategist

Modeling Details

Strategist

General features

- Fully Microsoft Windows compliant user interface
- User interface controls for
 - Data input and editing
 - Model run options
 - Array of output reports and diagnostics
 - Data management and custom reporting tools
 - Electronic Help documents
 - Model methodology
 - Data dictionary
- Modular architecture
 - Load forecast model: Load Forecast Adjustment Module (LFA)
 - Production cost model: Generation and Fuel Module (GAF)
 - Optimization model: PROVIEW™ (PRV)
 - Capital projects model: Capital Expenditure and Recovery Module (CER)

Strategist

General capabilities

- Customer load forecast model
 - Sales and losses
 - User controlled level of detail
 - Demand management programs
 - Conservation
 - Demand control or response
- Production cost model
 - Generation
 - Thermal, hydro, storage, renewable
 - O&M costs
 - Fuel contracts
 - Emissions tracking and allowance modeling
 - Power Contracts
 - Block energy purchase or sale
 - Put and call option contracts

Strategist

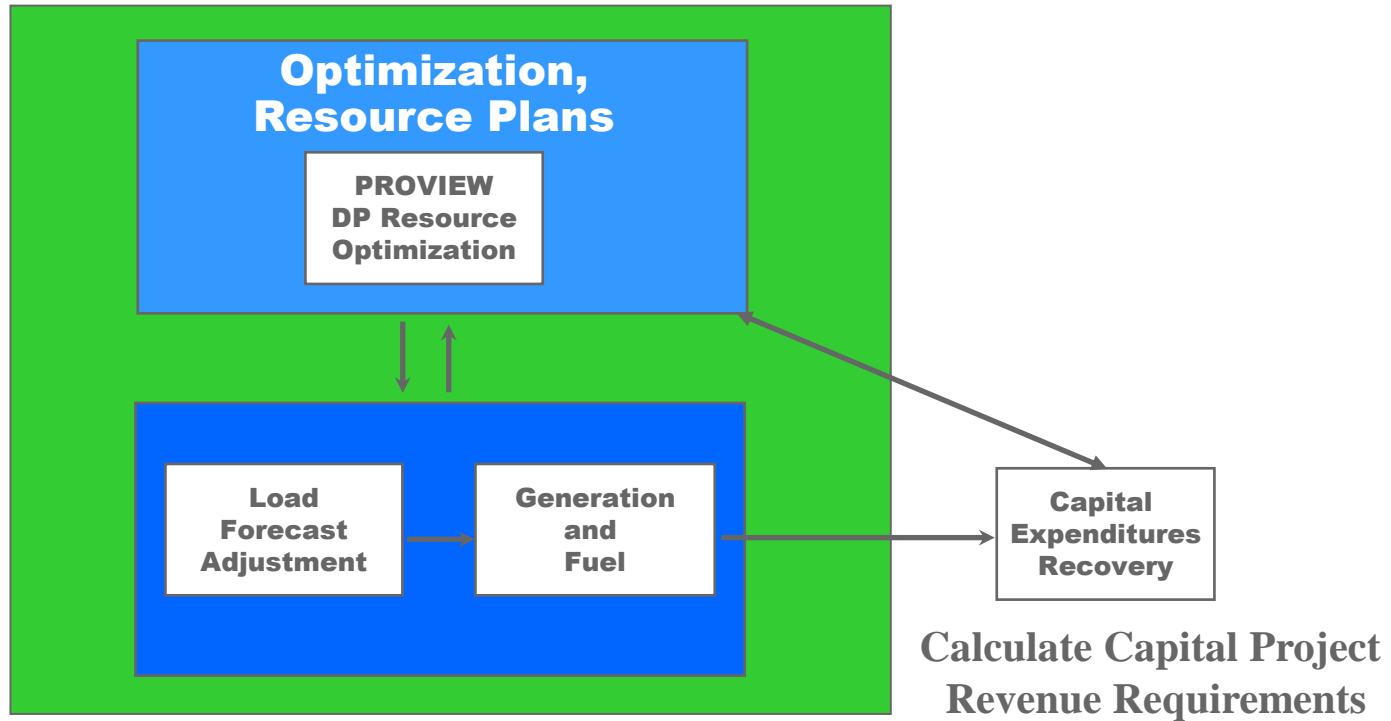
General capabilities

- Optimize future resource selections
 - Dynamic programming
 - Multiple feasible solutions
 - Multiple objective functions
 - Emissions caps & allowance trading
- System reliability
 - Reserve margin constraints
 - LOLH and unserved energy
 - Commitment and spinning reserve requirements
 - Automatic maintenance scheduling

Strategist

Integrated modules

Generate Portfolios
& Rank Plans

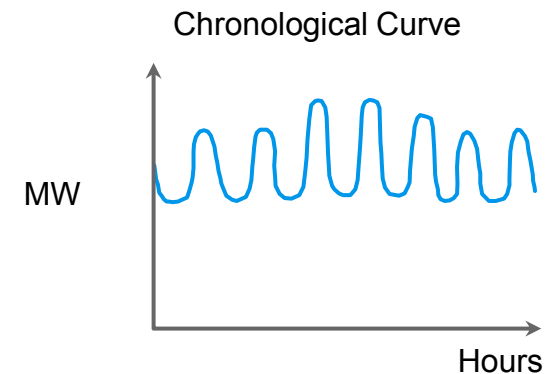


Aggregate Customer Loads & Apply Conservation Program Impacts Calculate Production Costs & Apply DLC

Strategist

Load Forecast Adjustment Module

- Not a load forecasting tool!
 - Where you store the load forecast information in the model
 - Applies changes to the forecast, such as new conservation or load shifting programs
- Customer loads are modeled in as much or as little detail as necessary for the analysis
 - Total system loads or broken into major customer classes
 - Monthly peak demand (mW) and energy (gWh) inputs
 - Hourly load shape represented by a 168 hour typical week per month
 - Model aggregates customer loads and applies adjustments to the company level
 - Passed to GAF module as an hourly 168 hour typical week per month
- Demand side resources
 - Peak demand and energy savings
 - Hourly impact shapes
 - Program costs
 - Demand control or response parameters



Strategist

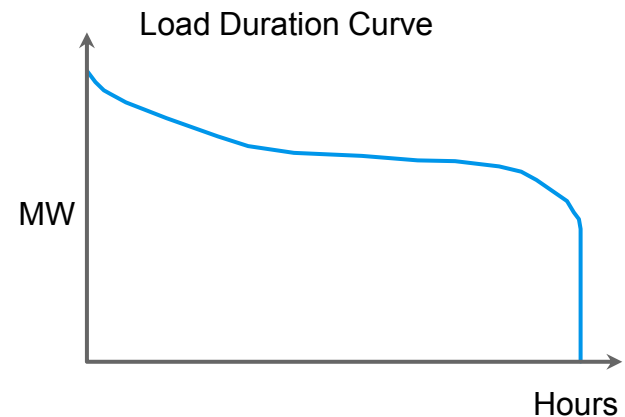
Generation and Fuel module

- Models the operation of the generation system:
 - Serve customer load
 - Satisfy power and capacity transfer contracts with other utilities
 - Economic power interchange with a power market
- Commit energy and capacity resources:
 - Load modifiers
 - Take or Pay bilateral transactions
 - Hydro
 - Renewable with an hourly generation pattern: solar, wind
 - Marginal cost dispatch
 - Storage (hydro pumped storage, batteries)
 - Put and call options
 - Economy energy interchange

Strategist

Generation and Fuel module

- Commit energy and capacity resources (continued):
 - Thermal generation is dispatched probabilistically against:
 - Remaining load in Load Duration Curve (LDC)
 - Method of convolution accounts for the probability of unserved energy due to unit forced outages.
 - Thermal resources in least cost economic order, subject to:
 - Must run status of some generation
 - Fuel availability constraints
 - Load following requirements (commitment criteria)
 - Spinning reserve requirements
 - Maintenance outages



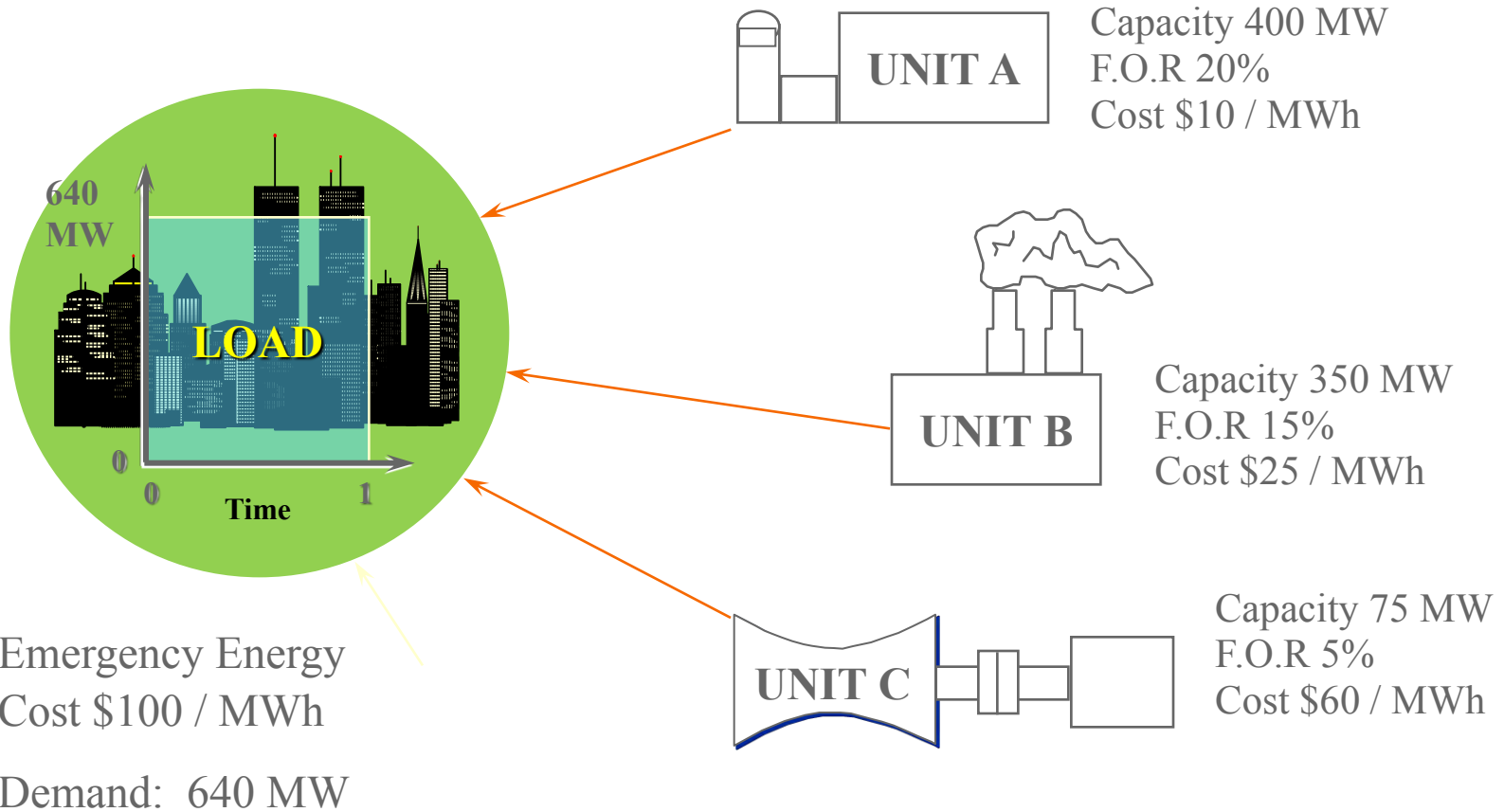
GAF Module

General thermal unit inputs

- Maximum and minimum capacities
 - Can also define several capacity states for each generator
- Heat rates
 - mmBtu per mWh of production
 - Can also define in terms of an incremental Heat Rate or a quadratic heat input power output curve
- Multiple fuel types and their costs
- Fixed and variable O&M costs
- Emissions production rates
- Forced outage rates (EFOR)
- Maintenance schedules or annual maintenance rates
- Capacity reserve contribution

Probabilistic Thermal Unit Dispatch

Unit uncertainty example



Probabilistic Simulation

Convolution method

- Combines the probability distribution of the unit outage with the probability distribution of the load

Probability Distribution Functions

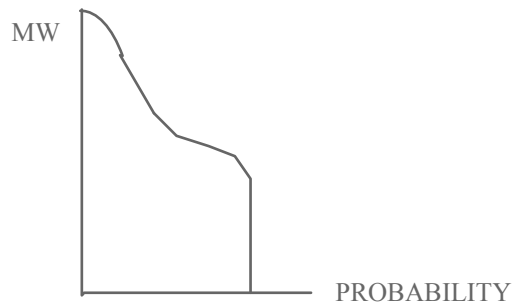
LOAD PROBABILITY DISTRIBUTION
FUNCTION

X

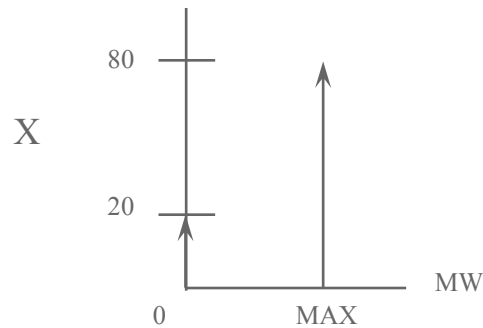
UNIT CAPACITY AVAILABILITY
PROBABILITY FUNCTION

=

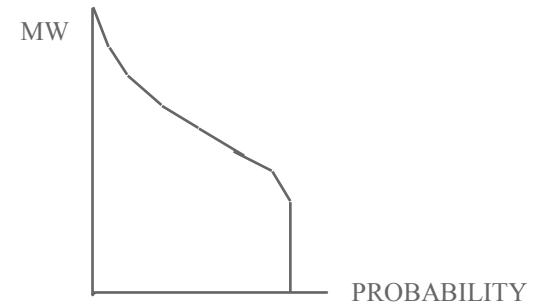
EXPECTED LOAD DISTRIBUTION
FUNCTION AFTER DISPATCH OF
CAPACITY



DISCRETE AVAILABILITY (%)

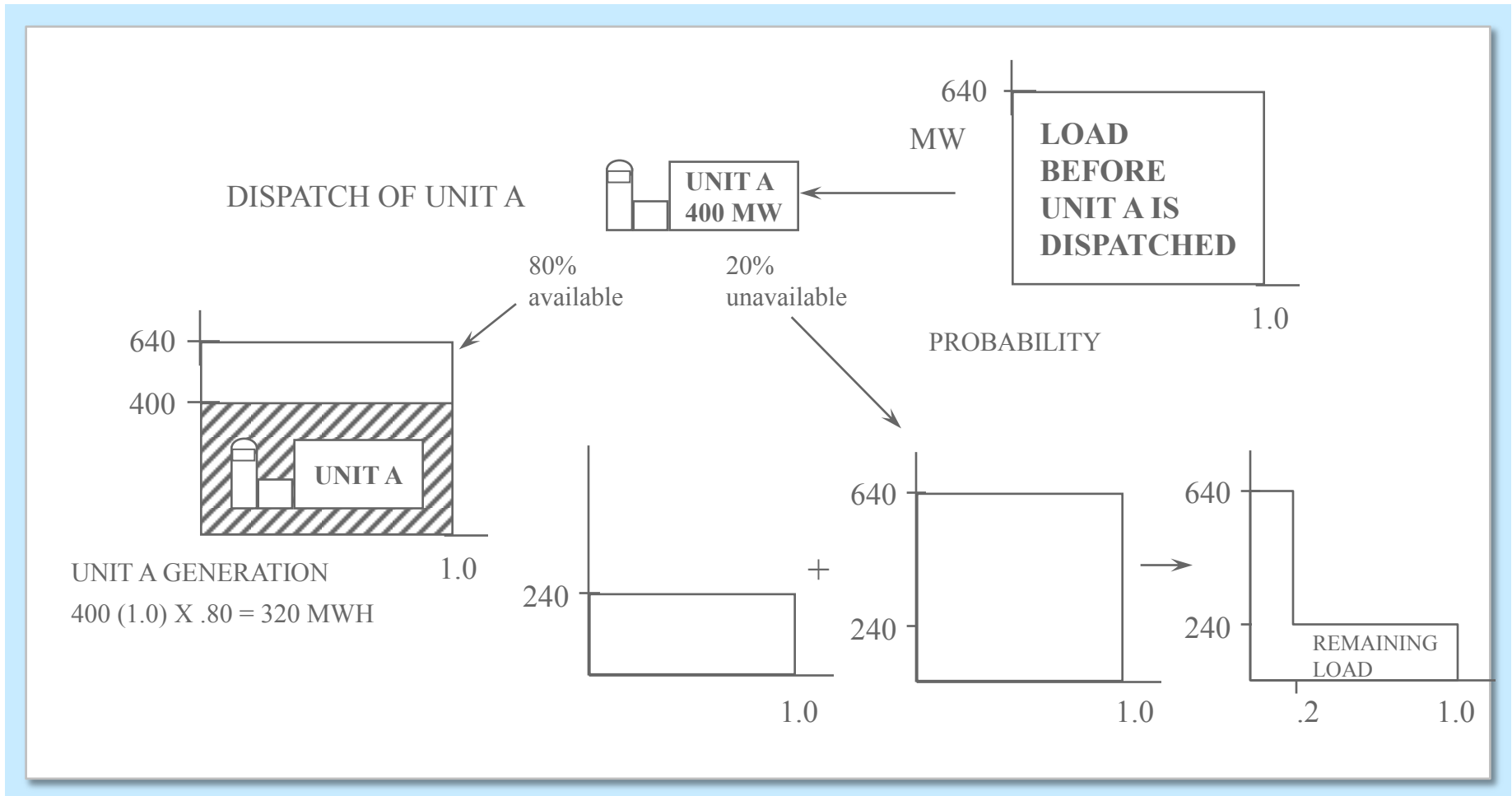


=



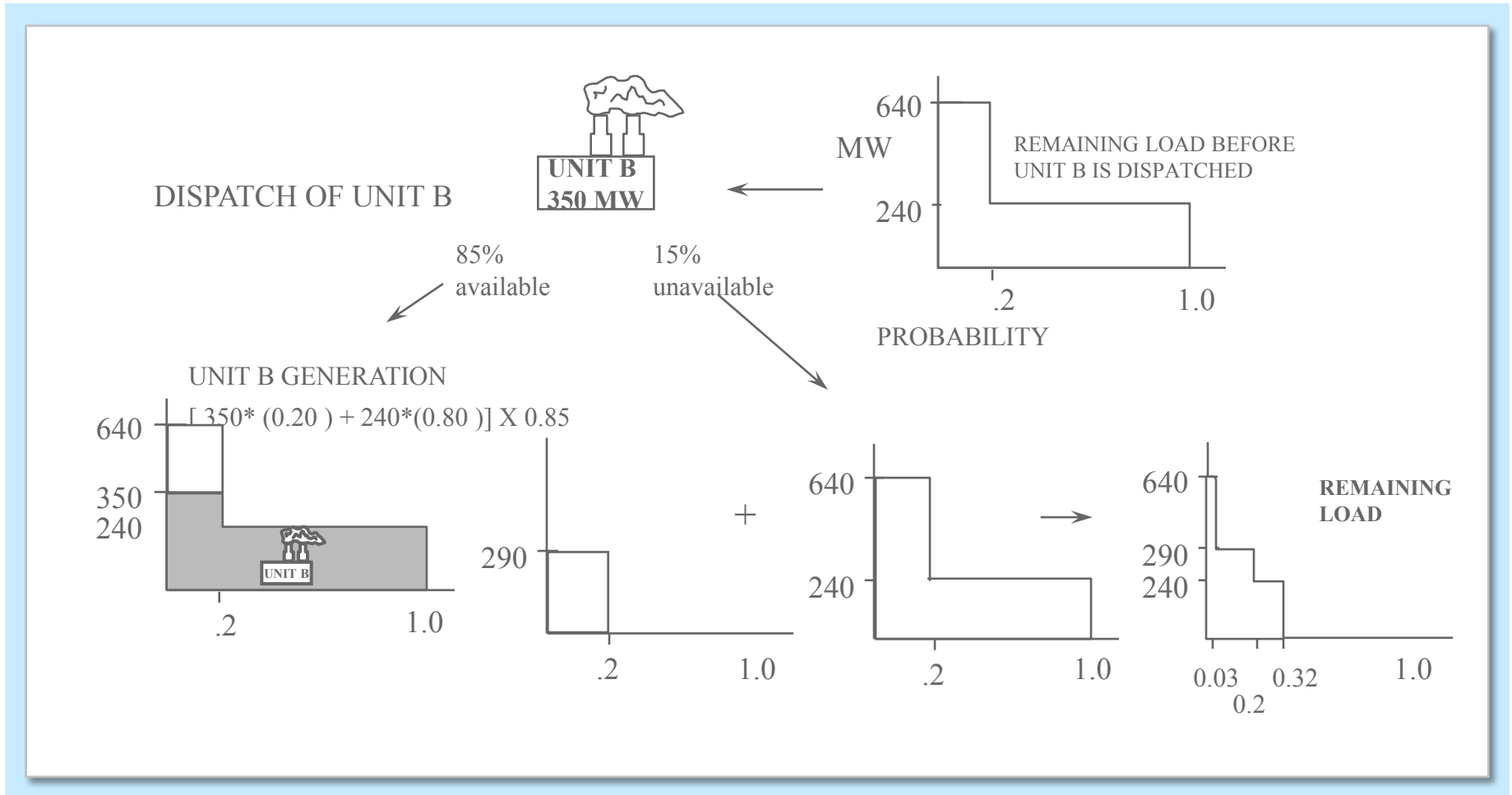
Probabilistic Simulation

Convolution method



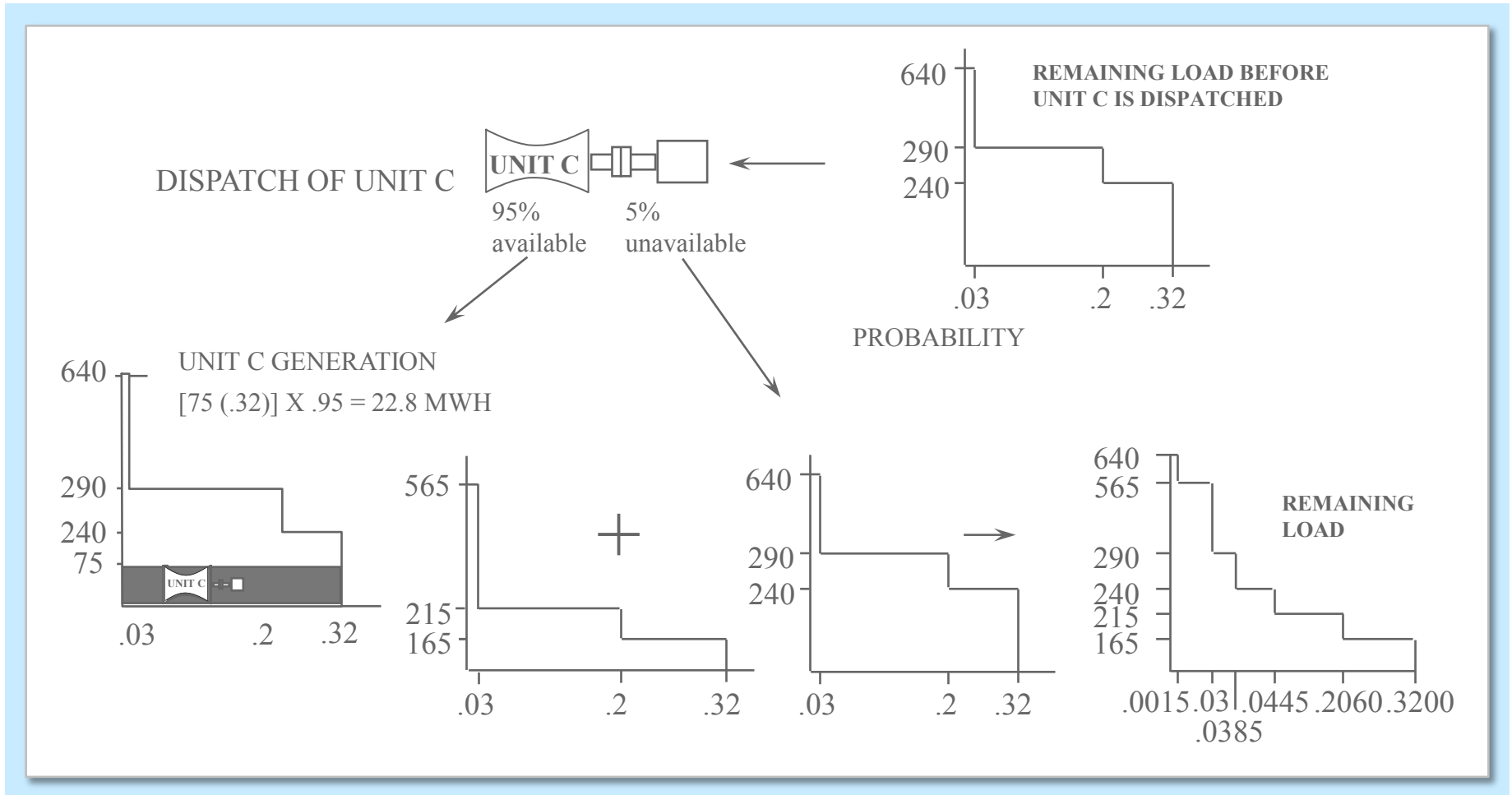
Probabilistic Simulation

Convolution method



Probabilistic Simulation

Convolution method



Probabilistic Simulation

Convolution method

- Expected generation:
 - Unit A = 320.0 mWh
 - Unit B = 222.7 mWh
 - Unit C = 22.8 mWh
 - Emergency = 74.5 mWh
- Expected production cost:
 - $(320 * 10) + (222.7 * 25) + (22.8 * 60) + (74.5 * 100) = \$17,585.50$
- Expected average cost of production:
 - \$27.48 / mWh
- Expected marginal cost:
 - \$49 / mWh

Strategist PROVIEW

- The function of PROVIEW is to determine the most cost effective choice and timing of possible future resources
- Considers economics and constraints of adding new resources
 - New or purchase existing thermal, hydro, storage, and renewable
 - New power contracts
 - Refurbishment, retrofit, repowering
 - Retire or mothball
 - Transmission Line Upgrades
 - Demand Side Management Programs
 - Emissions and RPS compliance
- PROVIEW optimizes the company's (or pool's) various alternatives while targeting an objective function, for example:
 - Minimization of PV utility revenue requirements (i.e. production and capital costs)
 - Minimization of PV total resource costs
 - Minimization of PV societal costs
 - Minimization of PV average electric rates

PROVIEW

Methodology

- PROVIEW utilizes a proprietary dynamic programming algorithm to optimize a sequence of interrelated decisions
- All possible combinations of new alternatives (type, amount, and timing), subject to input constraints, are given a full analysis over the planning period
- Plans are ranked for the study period based on the present value of the selected objective function
- Each plan may be evaluated beyond the end of the planning horizon (end effects analysis) using “levelized” costs and rates, and assuming replacement-in-kind for new alternatives
- Comparison Reports show plans side-by-side, ranked by either the Planning Period total or Study Period total (includes End Effects, if run)
- After an optimization, the top plan is automatically set up in the database, and the System Cost Report shows year-by-year production and capital costs
- Any plan generated by PROVIEW (not just the optimal one) may be set up in the database for further analysis

PROVIEW

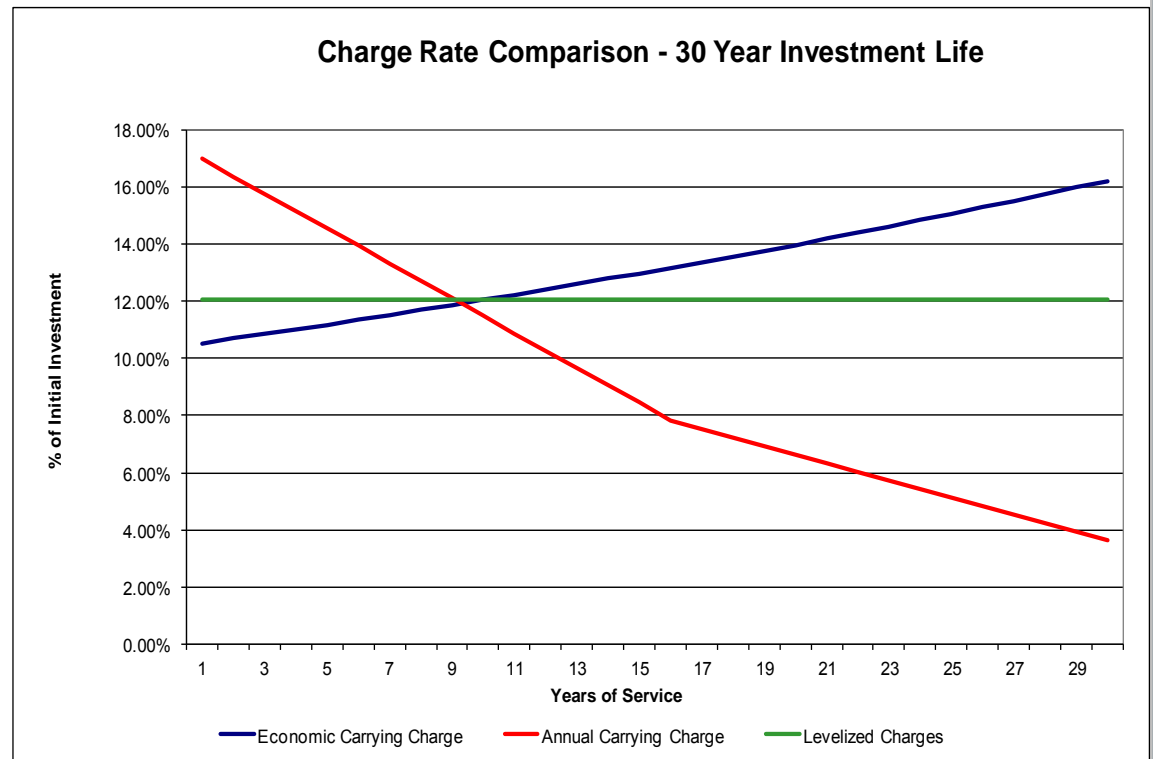
Optimization constraints

- System and company level constraints:
 - Reserve margin %
 - Emergency energy
 - Loss Of Load Hours
 - Emissions released
 - RPS requirements
- Constraints by alternative:
 - First and last year available
 - Annual minimum and maximum added
 - Cumulative minimum and maximum added
- Restricted Alternative Combinations:
 - Mutually Inclusive/Exclusive (enforced over the entire planning period)
 - Simultaneously Inclusive/Exclusive (enforced each year)
 - Dependent and Chained Alternatives

PROVIEW

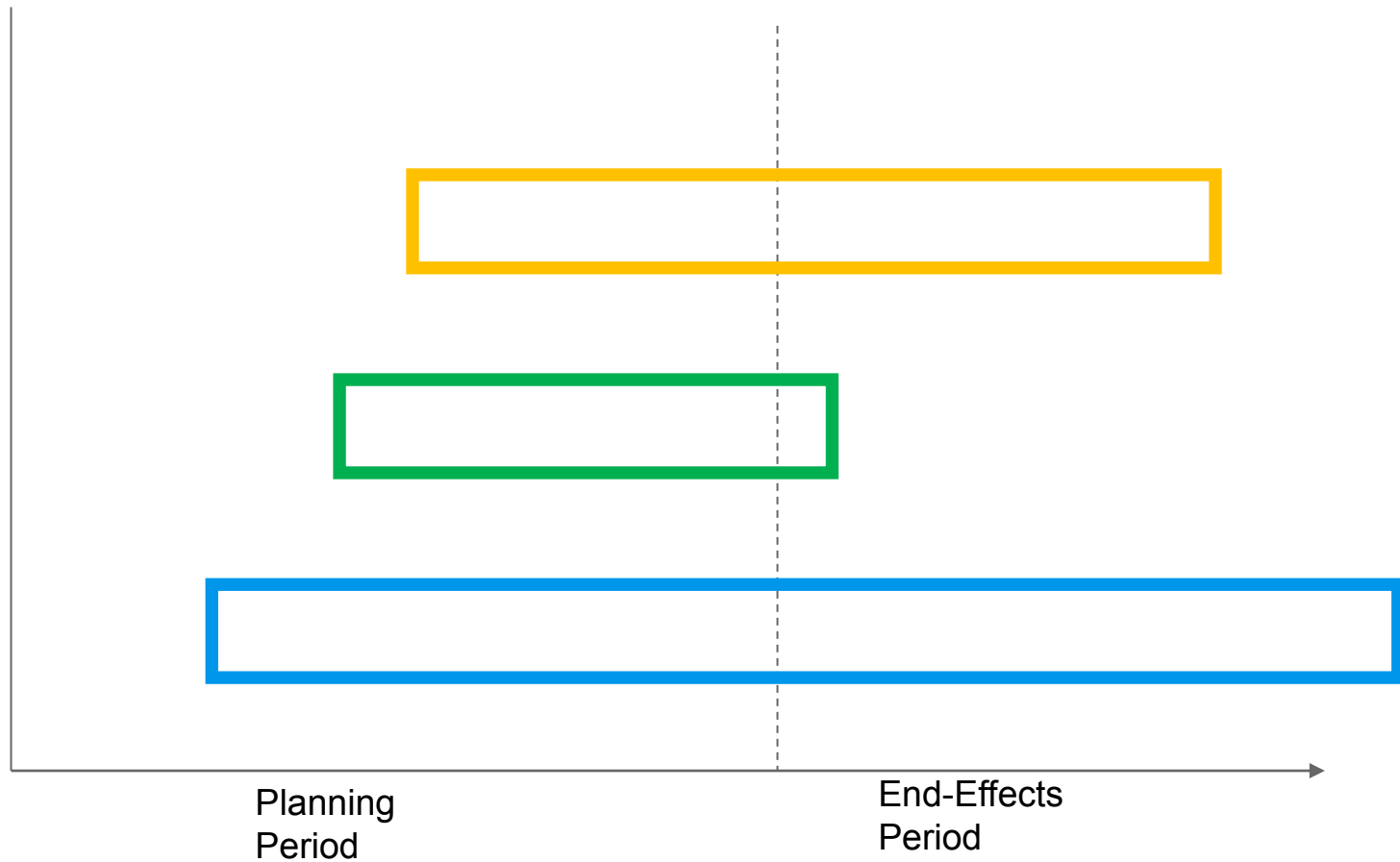
Treatment of capital costs

- Three methods:
 - Levelized carrying charge
 - Annual Carrying Charge
 - Economic Carrying Charge
- All three have same PV!
- How to consider costs beyond the Planning Period?
 - Capital costs
 - Operating costs



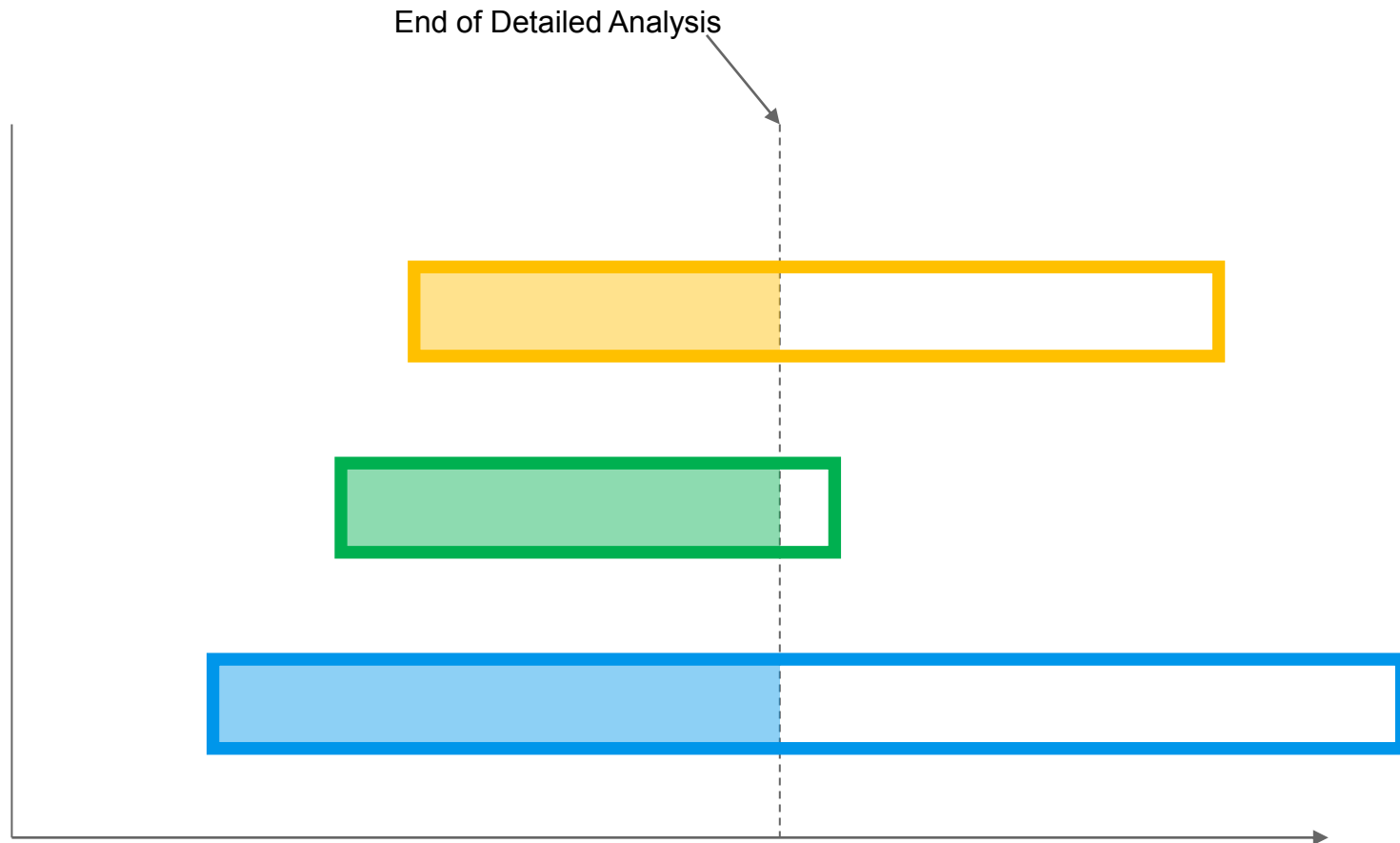
Treatment of Capital Costs

Comparing resources with different lifetimes



Treatment of Capital Costs

Detailed analysis for only partial lifetime



Treatment of Capital Costs

You can't just ignore the problem

- Including the entire lifetime of amortized capital costs of a resource, while only including its operating costs and benefits for a portion of its lifetime is an obvious bias against a high capital cost resource
- Two possible solutions:
 - Infinite End-Effects
 - Value of Deferral

Treatment of Capital Costs

Solution one: infinite end effects

- Assume infinite replacement-in-kind
- Estimate the operating costs over the infinite end-effects period
- Determine the capital costs associated with the infinite replacement-in-kind
- Include the following in your analysis:
 - Planning period operating costs
 - Estimated infinite end-effects period operating costs
 - Total planning period and infinite end-effects period capital costs
- Estimate operating costs to perpetuity
 - Freeze the system load and capacity as of the last year of the planning period
 - Sum the infinite series of the NPV of costs for all feedstocks
 - e.g. Fuel prices, O&M costs
 - The sum is finite as long as the discount rate exceeds the escalation rates!
 - Estimate the operating costs to perpetuity by performing one annual production cost simulation using the summed NPVs as the cost inputs

Solution One: Infinite End Effects

Determining capital costs to perpetuity

Sum the infinite series of the NPVs of the levelized carrying charges over the initial lifetime and over all of the lifetimes of the infinite number of replacements-in-kind.

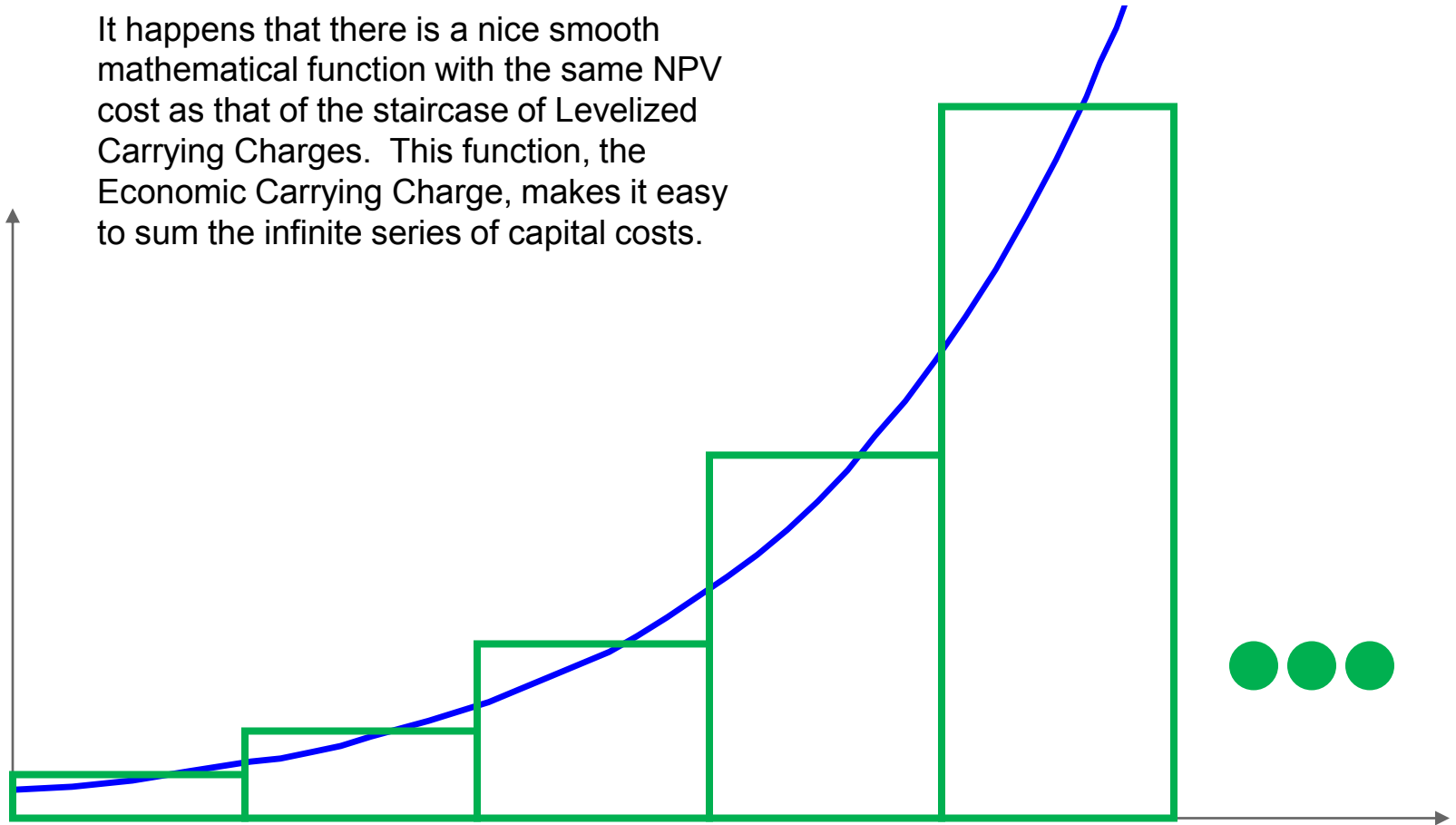


Solution One: Infinite End Effects

Capital cost calculation

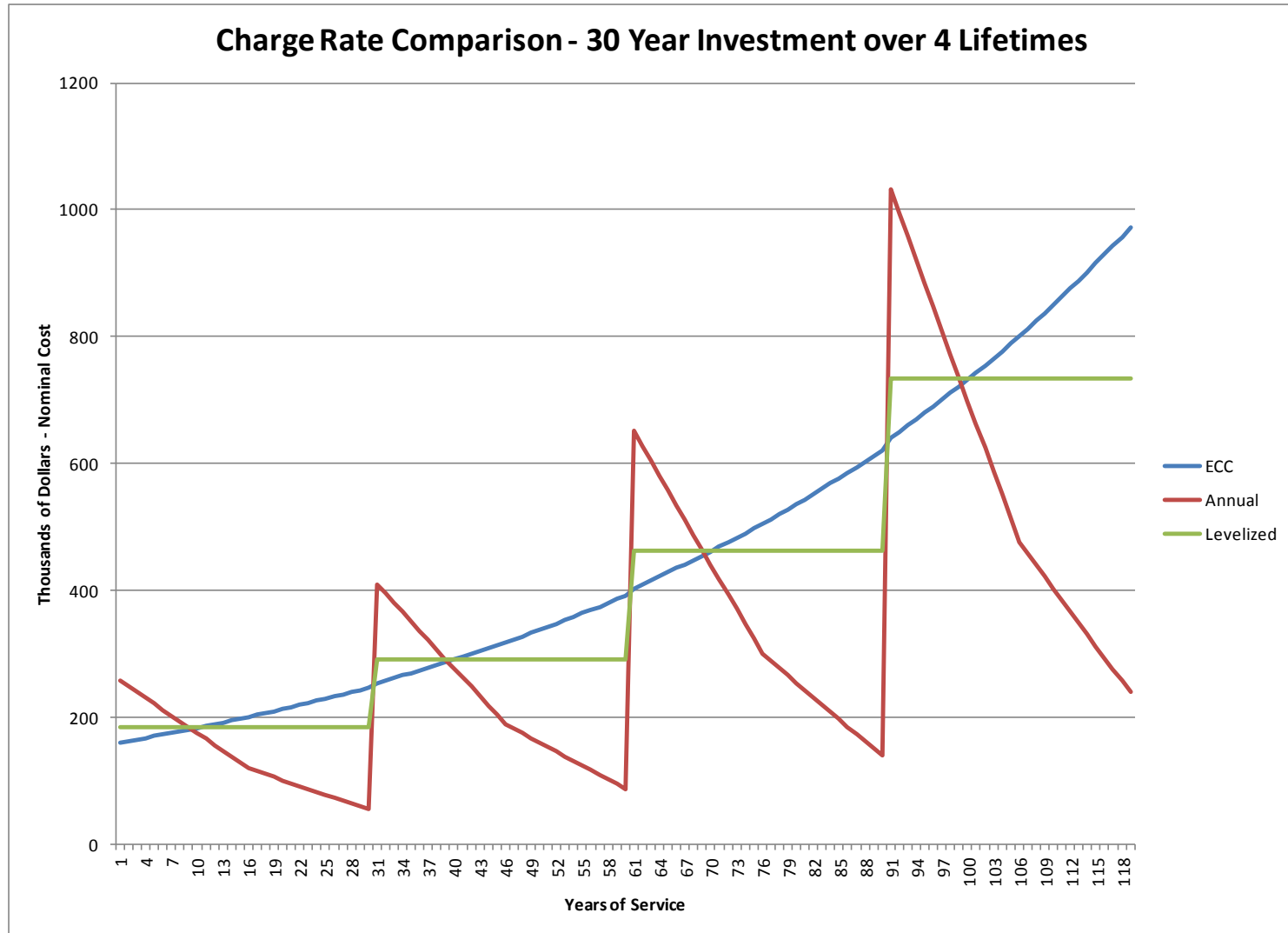
It happens that there is a nice smooth mathematical function with the same NPV cost as that of the staircase of Levelized Carrying Charges. This function, the Economic Carrying Charge, makes it easy to sum the infinite series of capital costs.

Annual Carrying Charge



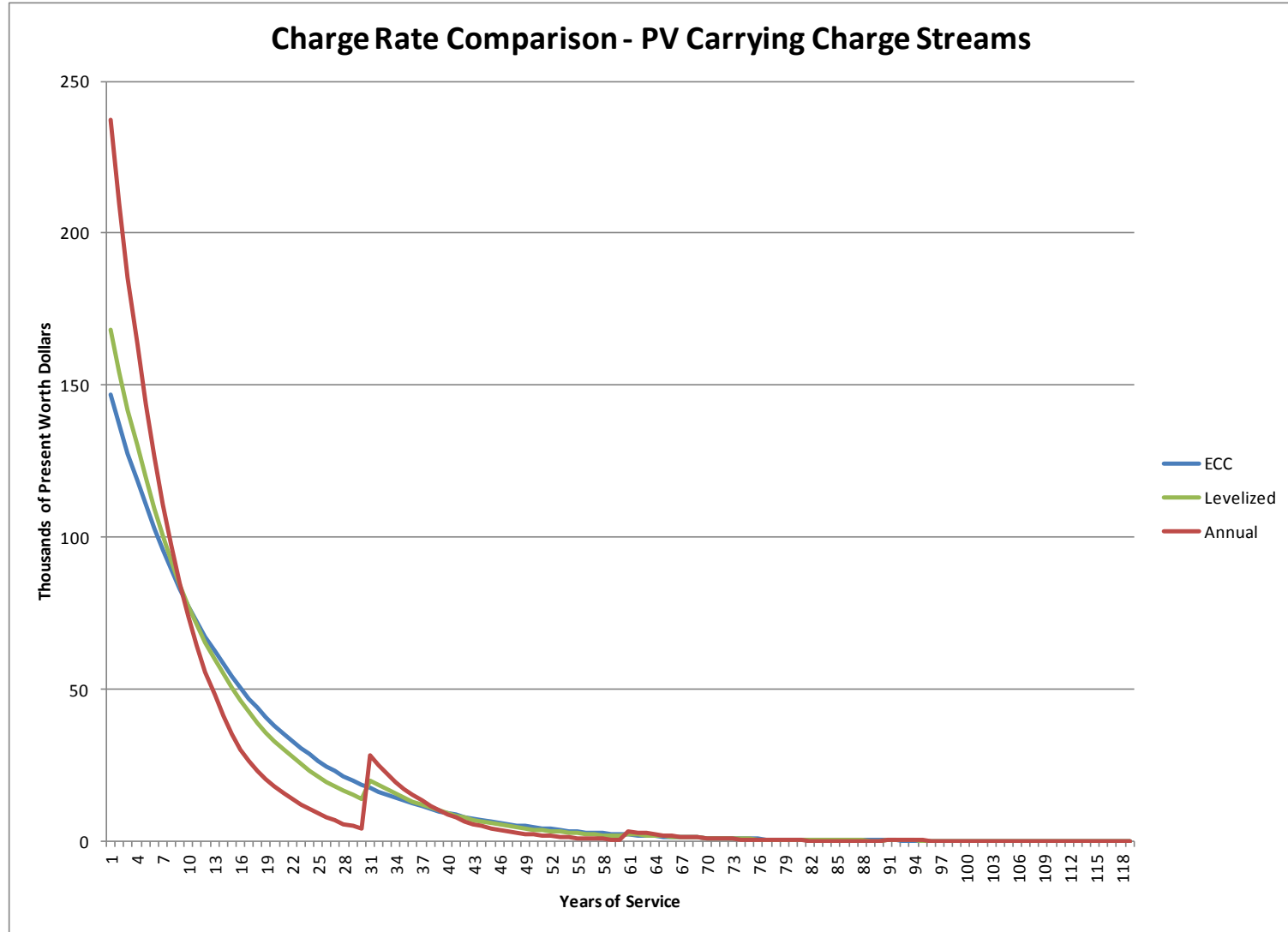
Capital Cost Calculations

Replacement in kind to perpetuity



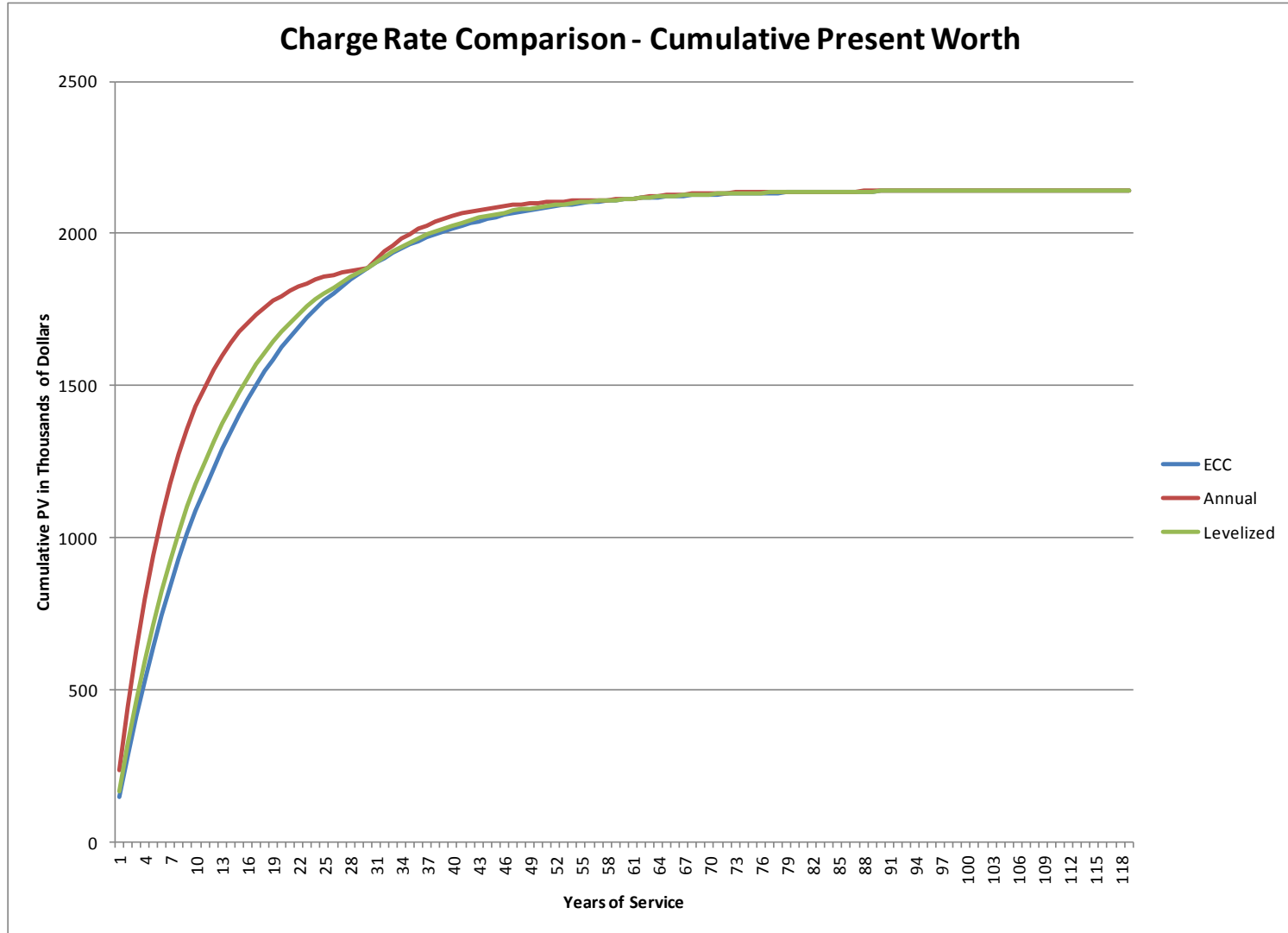
Capital Cost Calculations

Replacement in kind to perpetuity (cont.)



Capital Cost Calculations

Replacement in kind to perpetuity (cont.)



Treatment of Capital Costs

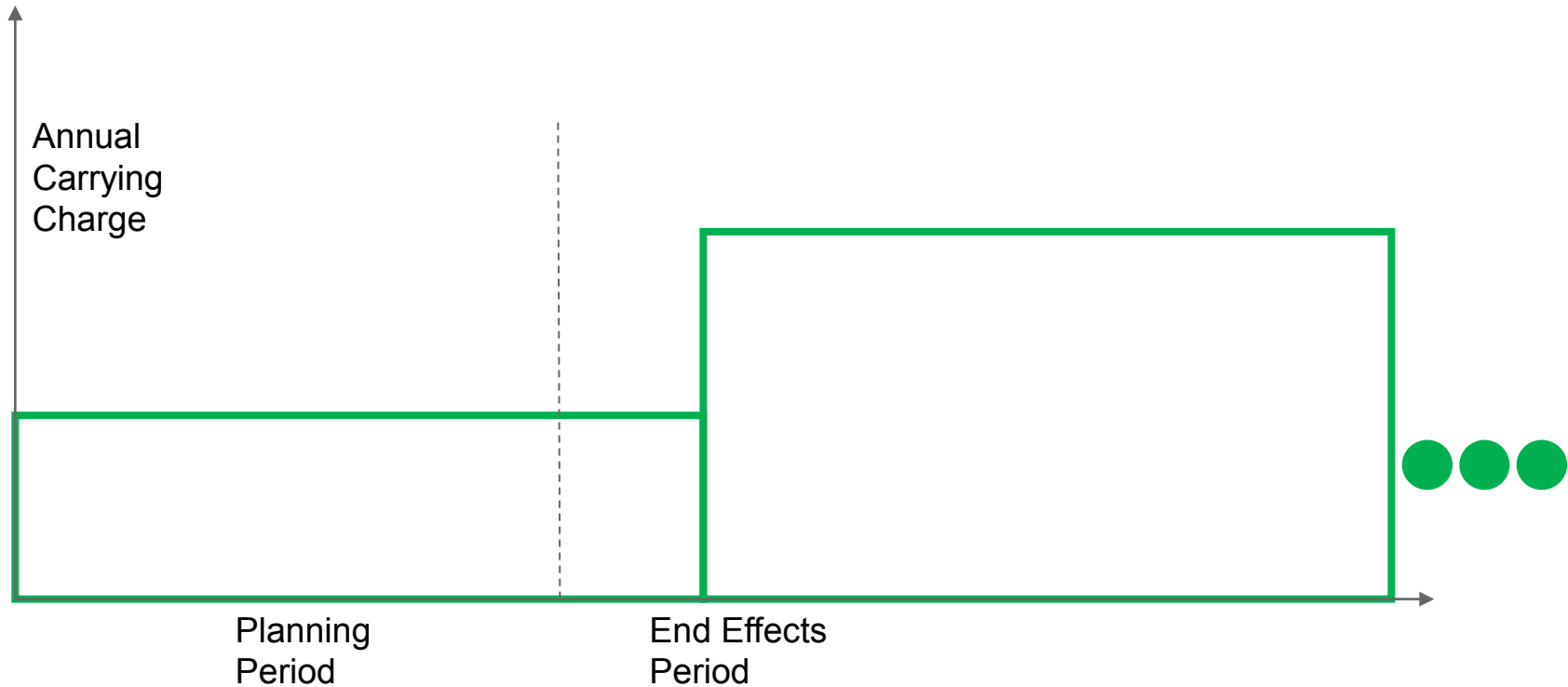
Solution two: value of deferral

- Assume infinite replacement-in-kind
- Determine the NPV sum of the capital costs associated with the infinite series of replacements-in-kind
 - For the initial commission year
 - And for the deferral to the first year beyond the planning period
 - The difference in NPV capital costs is the value of deferral of the resource to beyond the planning period
 - The value of deferral is an appropriate allocation of capital costs to the partial lifetime within the planning period
- Include the following in your analysis:
 - Planning period operating costs
 - Allocated planning period capital costs

Capital Cost Calculations

Solution two: value of deferral

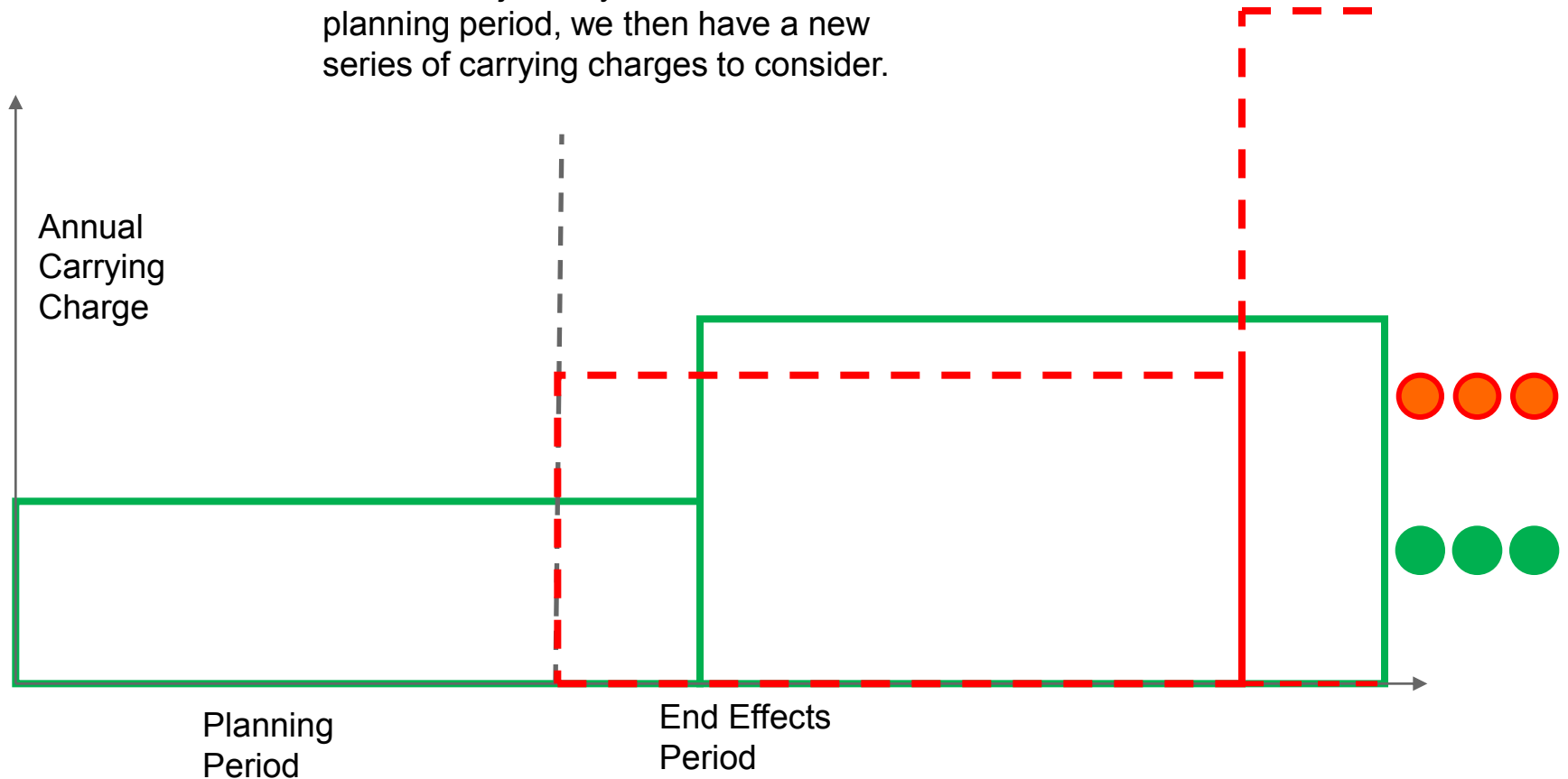
Here we are again with the series of annual carrying charges for the resource's infinite number of replacements-in-kind.



Capital Cost Calculations

Solution two: value of deferral

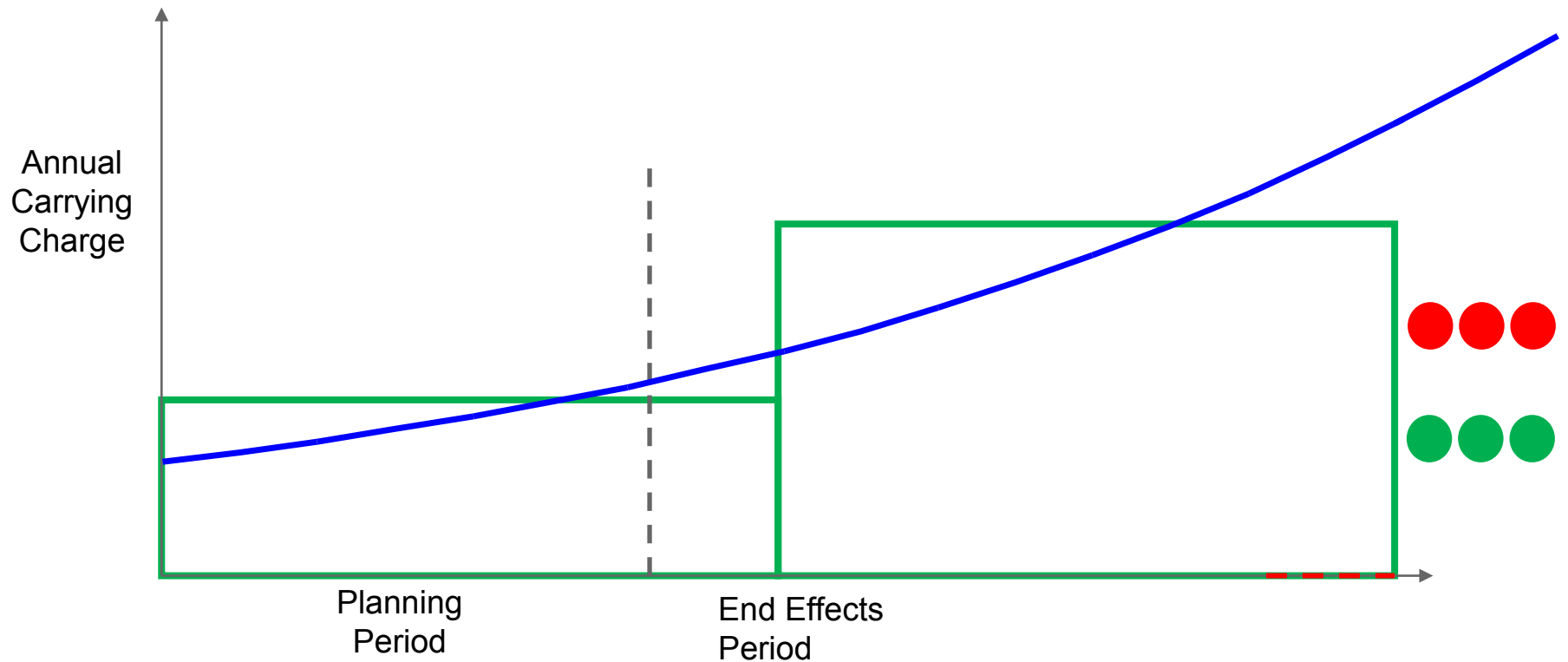
If we defer the commission of the resource to just beyond the end of the planning period, we then have a new series of carrying charges to consider.



Capital Cost Calculations

Solution two: value of deferral

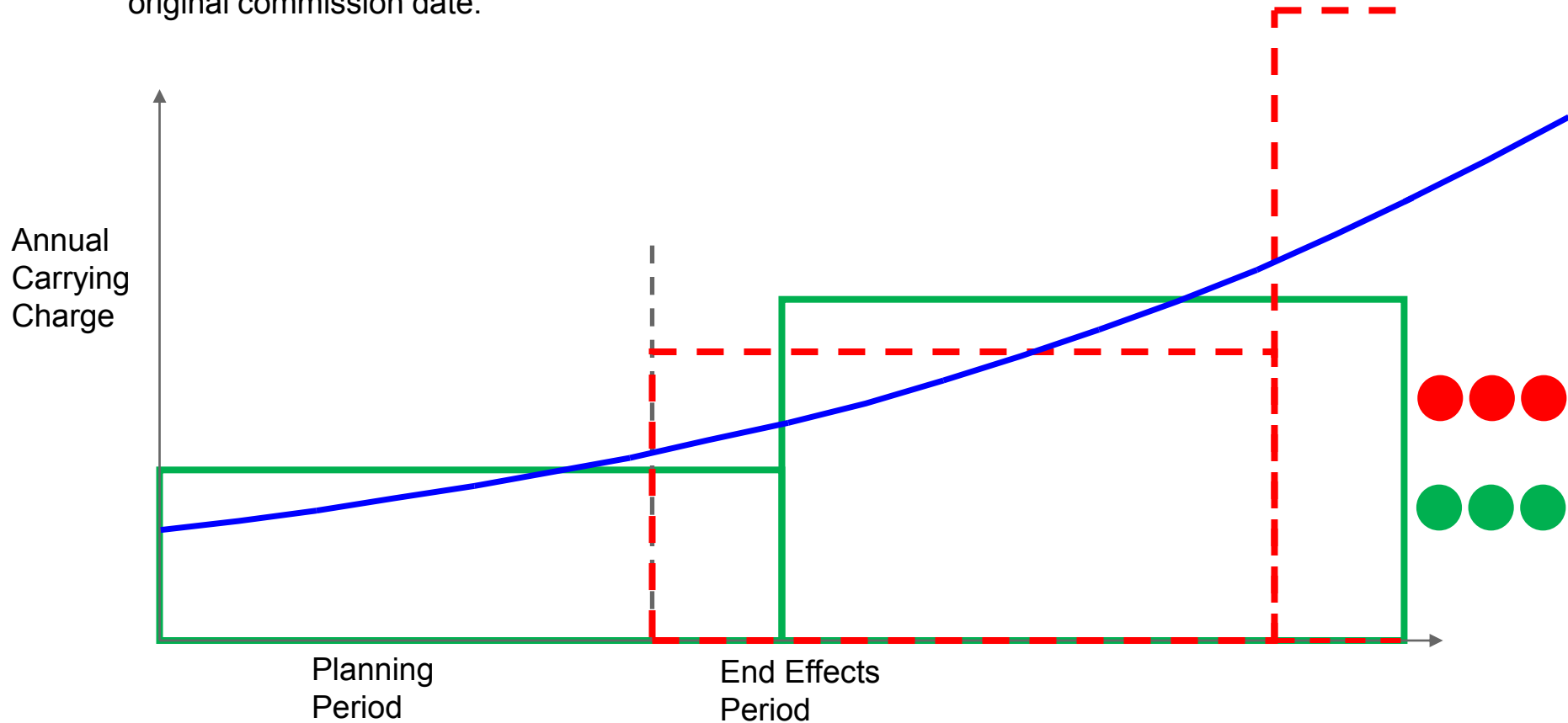
Luckily, we still have the Economic Carrying Charge function!



Capital Cost Calculations

Solution two: value of deferral

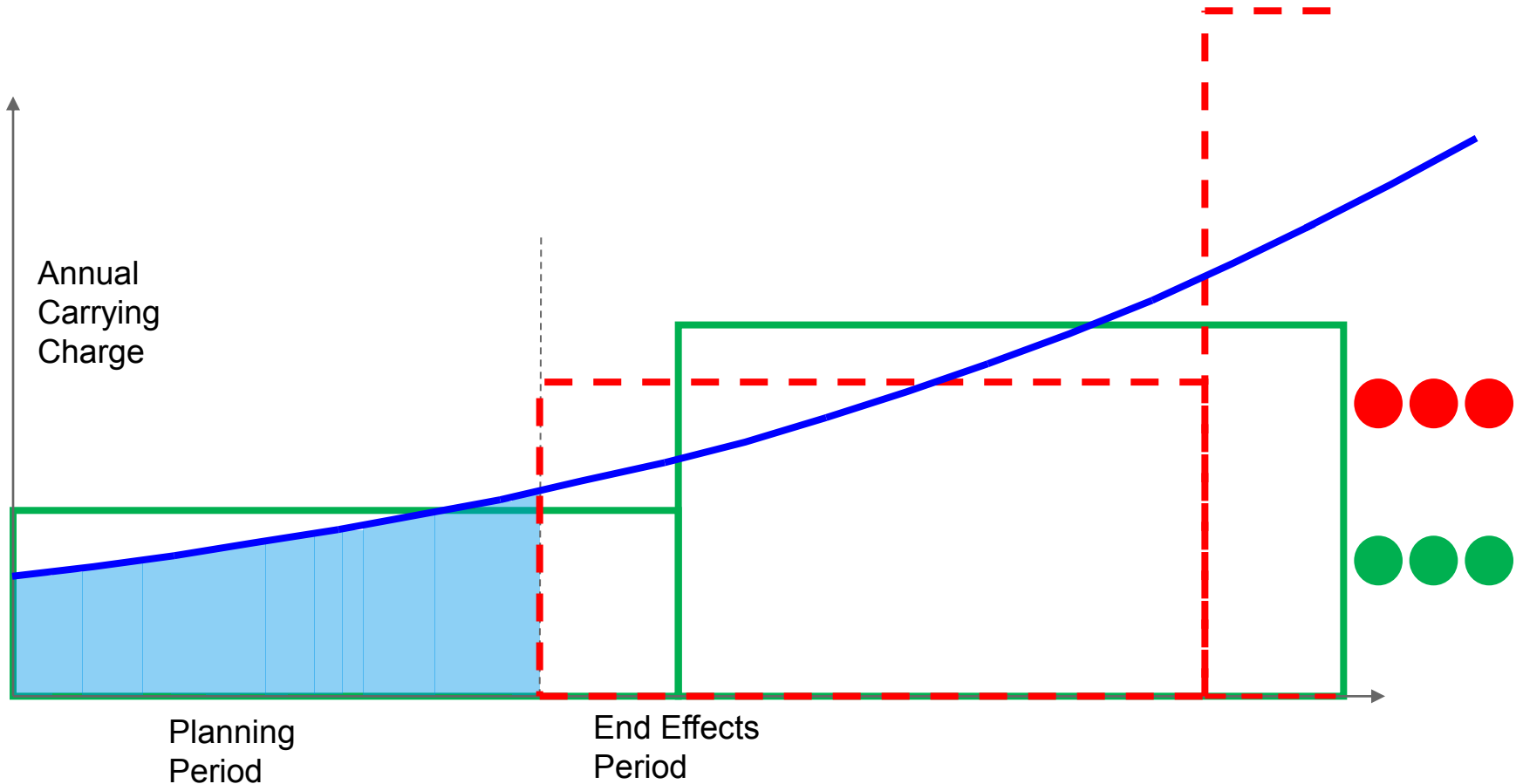
And when we look at the Economic Carrying Charges for the deferred resource, we see that they line up exactly on top of the Economic Carrying Charges for the original commission date.



Capital Cost Calculations

Solution two: value of deferral

Thus the only difference between the two NPV sums of infinite series of capital costs is the shaded area show below; this is the value of deferral



Capital Cost Calculations

ECC Methodology

- PROVIEW uses the Value of Deferral derived from the Economic Carrying Charge function to represent the capital cost “hit” for each resource commissioned within the Planning Period
- Since the ECC is an increasing function, the resource’s capital cost for the Planning Period is lower than an accounting treatment (i.e. – a decreasing Revenue Requirements cost stream)
 - Depending on the starting date for the resource and the end year of the Planning Period this may or may not also be true when compared to a levelized treatment.
- The Value of Deferral Method can be thought of as applying an appropriate “rental” payment for the Planning Period

Capital Cost Calculations

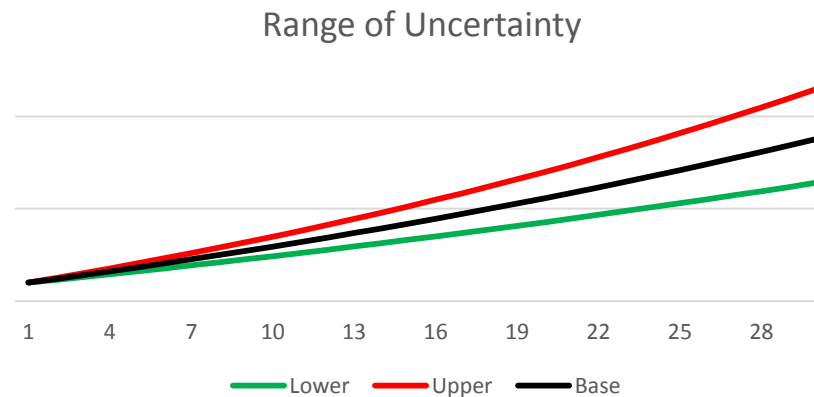
ECC Methodology

- The operating costs are calculated directly from the Planning Period Simulation.
- Thus, if the resource has lower operating costs than the other alternatives, this difference is captured even if the resource in question is commissioned in the final year of the Planning Period.
- The trade off between higher capital & lower operating costs vs. lower capital & higher operating costs is captured using this method.
- Resources with different lifespans are treated equally.
- The final rankings using ECC/Value of Deferral capital cost treatment with Planning Period only operating costs are exactly the same as those using levelized capital costs and infinite end effects analysis!

Resource Planning Risk Analysis

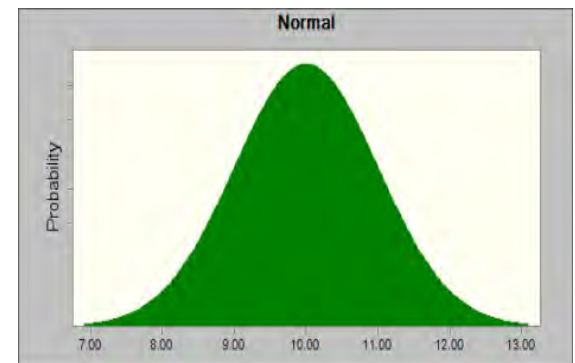
Risk Analysis Overview

- The vast majority of model inputs are based on forecasts
- Forecasts are uncertain, and that uncertainty can be expressed as a probability distribution
- The farther out in time you go, the wider the range of uncertainty becomes!
- Moreover; the next forecast cycle will undoubtedly change the forecast!
- Forecasts critical to the analysis:
 - Load
 - Fuel prices – particularly natural gas prices
 - Market energy prices – highly correlated with natural gas prices



Risk Analysis Overview

- Forecasts critical to the analysis (continued):
 - Capital cost of construction
 - General inflation rate
 - Escalation rates for cost items in addition to general inflation
 - General econometric forecasts (GDP, population, wage growth, etc.)
- Items becoming more important to the analysis:
 - Intermittent renewable generation
 - Wind
 - Solar
 - Both are dependent on weather!
 - Can change rapidly on a minute by minute basis



Risk Analysis

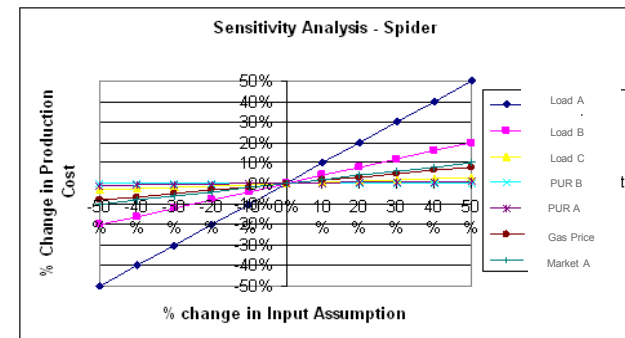
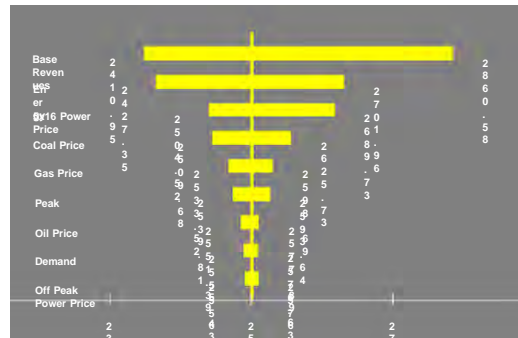
Approaches to analysis

- Scenario Planning
 - A scenario is a defined view of the future around which you build your forecasts
 - A scenario needs to have consistent assumptions across the board
 - Individual sources of uncertainty may be tied to underlying drivers (e.g. – economic activity)
 - Define a scenario by telling the story! It's a high level definition, so don't bog down in the minute.
 - It does not, per say, define the probability distributions of those forecasts
 - Sources of uncertainty to include in the scenario definition:
 - Environmental regulations
 - Market regulation/deregulation
 - Customer retention assumptions
 - Basic economic assumptions
 - Vendor financial stability
 - Technology changes

Risk Analysis

Approaches to analysis

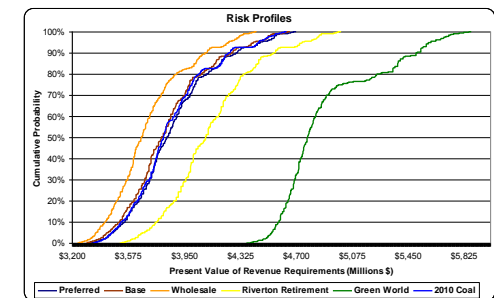
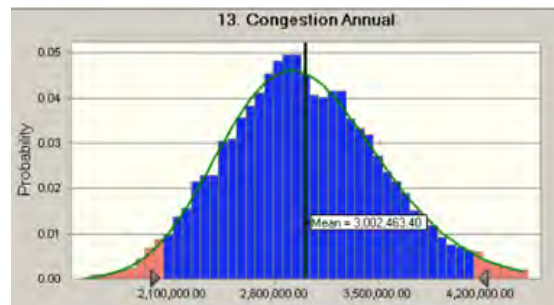
- Sensitivity Analysis
 - Select one of your uncertainty variables (i.e. – fuel prices)
 - Vary that variable across it's probability distribution
 - At p50 (mean or expected value)
 - And each of the two tails (i.e. – p10 & p90 or p5 & p95)
 - Also vary any correlated uncertainty variables (i.e. – market energy prices)
 - If the decision does not change across that range, then the decision is not sensitive to this uncertainty variable
 - If it does change, may need to test other distribution points (p20, p30, etc.) to determine inflection points



Risk Analysis

Approaches to analysis

- Stochastic analysis
 - For those uncertainty variables to which the decision is sensitive, and others that are correlated to them, perform a series of draws across the probability ranges to determine the values
 - Perform simulation runs in your model with the values from each draw
 - Typical number of draws is between 100 and 400 to get statistically significant convergence
 - Higher numbers are often used, but may be unnecessary
 - Compute the distribution parameters for the output values of interest (i.e. – PVRR)
 - Some simulation and optimization software applications have these capabilities built in
 - Results can be presented in a number of ways:
 - Histograms
 - Cumulative probability distributions



A B B