Beware Capital Charge Rates

The capital charge rate has a material effect in cost comparisons. Care should be taken to calculate it correctly and use it properly. The most common mistake is to use a nominal, rather than real, capital charge rate. To make matters worse, the common short-cut formula does not work well.

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I. Introduction

Beware capital charge rates. Typically, they are used incorrectly, and they often matter a lot.

In assessing investments that affect annual costs (such as fuel costs), it is helpful and convenient to convert the initial investment costs (a lump sum amount) into an annualized flow of capital charges. For example, a $100 initial investment is converted to $12 per year. The factors used to make these conversions are called ''capital charge rates'' or other terms of art. But in calculating and using these factors, there are important subtleties that apparently are not widely appreciated.

This article explains how these factors are often miscalculated and/or misused, resulting in incorrect investment decisions and public policy choices.

II. Revenue Requirements

A good way to think about calculating a capital charge rate is to start with the traditional revenue requirements that would be associated with an investment at a specified weighted average cost of capital (WACC).[1] These revenue requirements include depreciation, interest, taxes, and return on equity. Since the principal of

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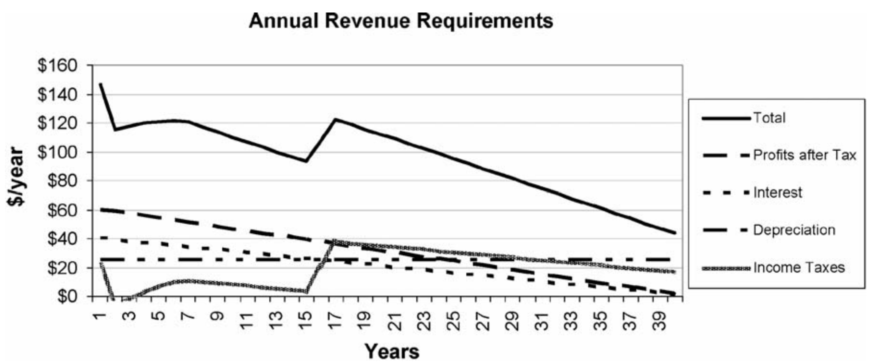

Figure 1: Revenue Requirements Stream Decreases over Time

the investment is depreciated each year, this stream of revenue requirements decreases over time (**Figure 1**).

The stream of total revenue requirements is not smooth due to the effects of accelerated depreciation on annual taxes.

III. Real versus Nominal

The critical distinction is that one can calculate a *real* capital charge rate or a *nominal* capital charge rate. A *real* capital charge rate is constant in real terms and hence increases with inflation in nominal terms. A *nominal* capital charge rate is constant in nominal terms and hence decreases with inflation in real terms. Revenue requirements are not constant in either real or nominal terms; they change every year, usually decreasing (**Figure 2**).

Both capital charge rates (real and nominal) can be calculated correctly. Both can be used correctly. But the common mistake is to use a nominal capital charge rate when a real capital charge rate should be used.

In calculating a capital charge rate, the first step is to calculate the present value of the stream of revenue requirements, where the discount rate is the nominal return on equity (ROE) in the WACC. Then, in calculating a nominal capital charge rate, this present value is levelized over the life of the investment. This can be done by dividing the present value by the sum of the nominal discount factors over the life of the investment.[2]

The real capital charge rate is calculated the same way except that the real ROE, not the nominal ROE, is used to levelize the same present value of the investment. The real ROE is the nominal ROE minus the effect of the inflation rate [the calculation is: real ROE = (1 + nominal ROE)/(1 + inflation rate) − 1].

The calculation of the nominal capital charge rate can be verified by taking the present value of the nominal capital charges, using the nominal ROE as the discount rate. This present value of the nominal capital charges will be the same as the present value of the revenue requirements, using the same discount rate.

The calculation of the real capital charge rate can be verified by taking the present value of the real capital charges, using the real ROE as the discount rate. It can also be verified by increasing the real capital charges each year by the inflation rate and then taking the present value of these inflated capital charges using the nominal ROE as the discount rate. These present values of the real capital charges (calculated either way) will be the same as the present value of the revenue requirements.[3]

The nominal capital charge rate is always higher than the real capital charge rate. Hence, the nominal initial capital charges are always higher than the real initial capital charges. (see Figure 2 and **Table 1**).

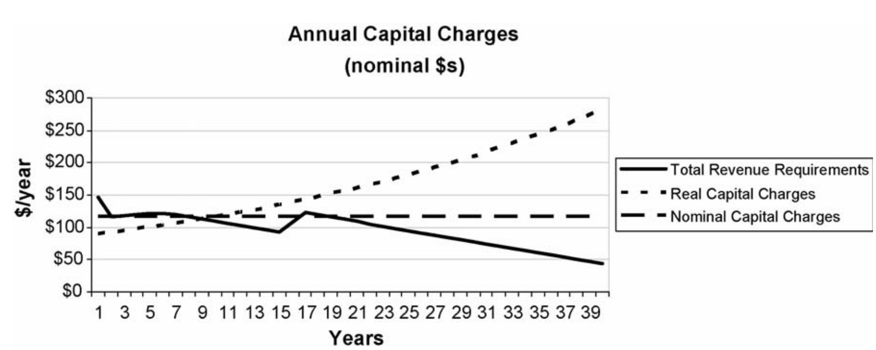

Figure 2: Revenue Requirements Are Not Constant in Real or Nominal Terms

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Table 1: Real vs. Nominal Capital Charge Rates

	Capital Charge Rate (%)	First Year Nominal Capital Charges $1,000 Investment
Real	8.6	$86
Nominal	11.5	$115
Percentage of increase	34	34

IV. Apples to Oranges

This distinction between real and nominal capital charge rates matters when one is comparing the total costs of one option to the total costs of another. Typically, the other costs and revenues are expressed (often implicitly) as costs that are constant in real terms (and hence increase with inflation). Fuel costs and operations and maintenance costs are usually treated this way. When this is the case, it is imperative that the annual capital charges are also expressed as constant in real terms, which means using a real capital charge rate. Using a nominal capital charge rate (where the capital charges are constant in nominal terms and decrease in real terms) with other costs that are constant in real terms amounts to comparing apples to oranges.

V. Example 1: Coal-Fired Power Plant versus Gas-Fired Combined Cycle Plant

A common use of capital charge rates is to compare the total costs of one type of power plant to another. In the example below, a coal plant is the least-cost option when a real capital charge rate is used. But when a nominal capital charge rate is used, a gas-fired combined-cycle (CC) plant appears to be the least-cost option. The choice of the capital charge rate determines the apparent least-cost option, as in Table 2.

The real capital charge rate is the correct choice because the other costs and revenues are deemed constant in real terms, not in nominal terms.

The nominal capital charge rate (with this WACC and related assumptions) is 34 percent higher than the real capital charge rate. Hence, the annual capital charges resulting from a nominal rate are 34 percent higher. This increase in the annual capital charges increases the coal capital charges by more in absolute terms than the gas capital charges, because the initial capital costs of the coal plant is higher (by about a factor of three).

Using a nominal capital charge rate with other costs that are constant in real terms will always bias the comparison against the option with higher initial capital costs. This is a mistake to be avoided, but unfortunately it is a very common mistake.

VI. Example 2: Setting the Cost of New Entry

In regional transmission organizations that use a demand curve as a part of their capacity market design, the cost of new entry is used to set the level of the demand curve.[4] The higher the calculated cost of entry, the higher the demand curve; the lower the cost

Table 2: Full Cost Comparison of Gas-Fired Combined Cycle and Coal-Fired Power Plant

	Real CCR		Nominal CCR	
	CC	Coal	CC	Coal
Real CCR (%)	8.6	8.6	11.5	11.5
Initial capital costs ($/kW)	$540	$1508	$540	$1508
Annual capital charges ($/kW-year)	$47	$130	$62	$174
FOM ($/kW-year)	$33	$33	$33	$33
Total fixed costs ($/kW-year)	$80	$164	$96	$208
Capacity factor (%)	85	85	85	85
Total fixed costs ($/mWh)	$10.8	$22.0	$12.9	$27.9
VOM ($/mWh)	$2.2	$3.3	$2.2	$3.3
Fuel ($/mWh)	$26.9	$11.8	$26.9	$11.8
Offsets ($/mWh)	$0.6	$1.3	$0.6	$1.3
Total variable ($/mWh)	$29.7	$16.4	$29.7	$16.4
Total costs ($/mWh)	$40.5	$38.4	$42.6	$44.3

Table 3: Calculation of Cost of Entry

	Real	Nominal
Capital charge rate (%)	8.6	11.5
Initial investment costs ($/kW)	$405	$405
Annual capital charges ($/kW-year)	$35	$47
FOM ($/kW-year)	$11	$11
Total fixed costs ($/kW-year)	$46	$58

of entry, the lower the demand curve. The cost of entry is deemed to be the full cost of adding a combustion turbine (sometimes this cost is reduced by the energy margin the new combustion turbine is assumed to earn). The full costs are the annual capital charges plus fixed operations and maintenance costs. Hence, if a nominal capital charge rate is used in computing the cost of entry, the demand curve will be higher, and if the use a real capital charge rate, the demand curve will be lower (**Table 3**).

Here the cost of entry varies by 26 percent, and the level of the demand curve would vary by the same amount (at the assumed WACC).[5]

The RTO market design filings do not discuss real versus nominal capital charge rates, but a review of the calculated costs of entry suggest that nominal capital charge rates are being employed. But in a real market, market participants do not expect all costs to remain constant in nominal terms. Given volatility, they expect costs to increase with inflation. Hence, a real capital charge rate should be used.

Using a nominal capital charge rate is equivalent to overstating the capital costs of the new combustion turbine by 34 percent (at the assumed WACC). A nominal capital charge rate will result in demand curves that are too high, and this is turn will result in too much capacity being built, *ceteris paribus*.

VII. Example 3: Calculating the Cost per Ton of CO_2 Removed

Another application of capital charge rates is in calculating the cost per ton removed of a pollutant. Given the current focus on global climate change, the cost per ton of CO_2 removed has become an important number. Since most of the options for reducing CO_2 emissions have high capital costs, the capital charge rate is a very important parameter.

The effect of capital charge rates, of course, is the same. Using a nominal capital charge rate when a real capital charge rate should be used will exaggerate the calculated cost per ton removed (**Table 4**).

Table 4 shows the effects of using nominal capital charge rates rather than real capital charge rates for four options. The first option is a pulverized coal plant (PC), which is often the least-cost option for providing baseload power, when there is no tax on CO_2 or allowance value for CO_2. The second is an integrated gasifier combined cycle plant with carbon capture and sequestration. This plant has about the same efficiency as PC, but the concentration of CO_2 in its flue gas reduces the costs of carbon capture; about 85 percent of the CO_2 could be captured and sequestered. The third is nuclear, which has higher all-in costs than PC but no CO_2 emissions. The fourth is a hypothetical efficiency investment with very high capital costs and no other costs.[6]

Since, in this example, the other costs are assumed to be constant real terms, the real capital charge rate is the correct choice. The effect of using a nominal capital charge rate (incorrectly) is to exaggerate the capital costs. Since the options that reduce CO_2 emissions have higher initial capital costs, the total costs of these options is increased more than the total costs of PC, when a nominal CCR is used rather than a real CCR. Hence, the effect of using a nominal capital charge rate incorrectly is to increase the cost per ton removed (**Table 5**).

The effect on the IGCC (13 percent) is less than the others, because capital costs are a lower proportion of total costs; non-capital costs also increase when carbon capture and sequestration is added. The effect on nuclear (39 percent) is greater because capital charges are a higher proportion of total costs. The effect on the efficiency investment is greatest (105

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Table 4: Using Nominal Capital Charge Rates Rather than Real Capital Charges, Four Options

	Real CCR				Nominal CCR			
	PC	IGCC	Nuclear	Efficiency	PC	IGCC	Nuclear	Efficiency
Cost per ton of CO_2 removed								
CCR (%)	8.6	8.6	9.8	10.3	11.5	11.5	13.1	13.8
Investment ($)	$1,508	$2,146	$2,631	$3,500	$1,508	$2,146	$2,631	$3,500
Annual capital charges ($/kW-year)	$130	$185	$257	$361	$174	$248	$345	$483
FOM ($/kW-year)	$33	$33	$89	$0	$33	$33	$89	$0
Total fixed costs ($/kW-year)	$164	$219	$347	$361	$208	$281	$434	$483
Capacity factor (%)	85	85	85	85	85	85	85	85
Total fixed costs ($/mWh)	$22.0	$29.3	$46.5	$48.4	$27.9	$37.8	$58.3	$64.9
VOM ($/mWh)	$3.3	$11.7	$0.0	$0.0	$3.3	$11.7	$0.0	$0.0
Fuel ($/mWh)	$11.8	$14.5	$6.7	$0.0	$11.8	$14.5	$6.7	$0.0
Offsets ($/mWh)	$1.3	$1.6	$0.0	$0.0	$1.3	$1.6	$0.0	$0.0
Total variable ($/mWh)	$16.4	$27.8	$6.7	$0.0	$16.4	$27.8	$6.7	$0.0
Total ($/mWh)	$38.4	$57.2	$53.2	$48.4	$44.3	$65.6	$65.0	$64.9
CO_2 emissions (lbs/mWh)	1916	236	0	0	1916	236	0	0
Tons removed (tons/kW-year)		6	7	7		6	7	7
Costs ($/kW-year)		$140	$111	$75		$158	$154	$153
Cost per ton removed ($/ton)		$22	$16	$10		$25	$22	$21
Percentage difference (%)						13	39	105

percent), because capital charges represent 100 percent of total costs.

Clearly then, we see from this example (as from the examples above) that using a nominal CCR when a real CCR should be used leads to material errors.

VIII. Shortcut Does Not Work Well

As discussed above, a common mistake is to use a nominal capital charge rate when a real one should be used. To make matters worse, capital charge rates (nominal and real) are often miscalculated.

In calculating the capital charge rate, some practitioners use the following formula:

$$\frac{i}{1-(1+i)^{-n}}$$

where i is the discount rate and n is the length of the investment. This is actually the same as the ''PMT'' function within an Excel spreadsheet.

This formula is designed to calculate a constant annual amount. In concept, if a nominal discount rate were used (as i), it would compute a nominal CCR, and if a real discount rate were used (as i), it would compute a real CCR. But this formula only works when the tax rate is zero. Note this formula has no term (t) for taxes.

When the tax rate is positive, then the user must decide what discount rate to use. If the after-tax WACC is used, as described above, the formula results in a capital charge rate that is too low. This is because it ignores that taxes must be paid on profits.

If a before-tax WACC is used (where the WACC is divided by one minus the tax rate), then the

Table 5: Cost per Ton of CO_2 Removed

	Real CCR	Nominal CCR	Percentage of increase
IGCC	$22	$25	13
Nuclear	$16	$22	39
Efficiency	$11	$21	105

formula results in a capital charge rate that is too high. This is because it ignores the effect of accelerated depreciation for tax purposes.

If an in-between WACC is used, such as one that does not adjust the cost of debt for the effect of taxes, then the formula yields an annual payment that is too low with no debt (since it ignores the taxes that must be paid on profits), too high with a lot of debt (since it ignores the tax-deductibility of interest), and about right somewhere in between. Or if an in-between WACC is used where the cost of equity is increased and the cost of debt is reduced, both to account for taxes, then the annual payment is too high with no debt, too low with no equity (both because the effect of accelerated depreciation on taxes is ignored), and about right somewhere in between.

Hence, this formula should be considered a crude approximation that should be avoided whenever reasonable levels of accuracy are desired.[7]

IX. Conclusion

The capital charge rate has a material effect in cost comparisons. Care should be taken to calculate it correctly and use it properly. The most common mistake is to use a nominal capital charge rate when a real capital charge rate should be used. To make matters worse, the common short-cut formula does not work well. While the correct capital charge rate adds additional complication and sophistication to economic analyses, the bother is worth it. The alternatives can vitiate the entire analysis.■

If an in-between WACC is used, then the formula yields an annual payment that is too low.

Endnotes:

1. For purposes of this article, we are assuming the WACC is 8.5 percent, based on the following assumptions. The capital structure is 50 percent debt and 50 percent equity. The interest rate on debt is 8 percent. The return on equity is 12 percent. Tax rate is 38 percent. Hence, the after-tax WACC is 50 percent × 8 percent(1 − 38 percent) + 50 percent × 12 percent, which equals 8.5 percent. Also, we are assuming the inflation rate is 3 percent, the life of the investment is 40 years, and the tax life is 15 years.

2. This can also be done using the ''PMT'' function in an Excel spreadsheet.

3. Also, these calculations can be verified by calculating the present value of returns on equity. In each case, this present value will equal the initial equity investment, which is 50 percent of the initial capital investment with the WACC we are using.

4. It is also used to set the ''deficiency charge'' in RTOs that use this concept.

5. In a separate article (published elsewhere in this issue), I explain how the effect of capacity market design on the WACC is material, because the more stable the market, the lower the WACC, and vice versa.

6. The WACC for nuclear was increased from 8.5 percent to 9.7 percent, to reflect greater risk. The WACC for efficiency was increased to 12 percent, because it was conservatively assumed that such investments would require 100 percent equity financing. These increases in WACC have no effect on the calculation of the effect of using a nominal CCR rather than a real CCR.

7. Readers who want a reasonably transparent spreadsheet that will calculate both real and nominal capital charge rates given user-provided inputs on capital structure, costs of debt and equity, investment life, tax rates and accelerated depreciation, and inflation, are invited to send an email request to hoff@hoffstauffer.com.

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