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**Authors**
LaCommare, Kristina Hamachi
Edwards, Jennifer L.
Gumerman, Etan
et al.

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# Distributed Generation Potential of the U.S. Commercial Sector

*Kristina Hamachi LaCommare, Jennifer L. Edwards, Etan Gumerman, and Chris Marnay*

**Environmental Energy Technologies Division**

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## Disclaimer

# Distributed Generation Potential of the U.S. Commercial Sector

Kristina Hamachi LaCommare
Lawrence Berkeley National Laboratory, USA
Environmental and Energy Technologies Division
One Cyclotron Road, MS 90R4000
Berkeley, CA 94720-8136
email: KSHamachi@lbl.gov

Jennifer L. Edwards
Lawrence Berkeley National Laboratory, USA
Environmental and Energy Technologies Division
One Cyclotron Road, MS 90R4000
Berkeley, CA 94720-8136
email: JLEdwards@lbl.gov

Etan Gumerman
Lawrence Berkeley National Laboratory, USA
Environmental and Energy Technologies Division
One Cyclotron Road, MS 90R4000
Berkeley, CA 94720-8136
email: EZGumerman@lbl.gov

Chris Marnay
Lawrence Berkeley National Laboratory, USA
Environmental and Energy Technologies Division
One Cyclotron Road, MS 90R4000
Berkeley, CA 94720-8136
email: C_Marnay@lbl.gov

## Keywords

Distributed generation, National Energy Modeling System (NEMS), gas turbine, gas engine, microturbine, combined heat and power (CHP), distributed energy resources (DER)

## Abstract

Small-scale (100 kW-5 MW) on-site distributed generation (DG) economically driven by combined heat and power (CHP) applications and, in some cases, reliability concerns will likely emerge as a common feature of commercial building energy systems in developed countries over the next two decades. In the U.S., private and public expectations for this technology are heavily influenced by forecasts published by the Energy Information Administration (EIA), most notably the Annual Energy Outlook (AEO). EIA's forecasts are typically made using the National Energy Modeling System (NEMS), which has a forecasting module that predicts the penetration of several possible commercial building DG technologies over the period 2005-2025. Annual penetration is forecast by estimating the payback period for each technology, for each of a limited number of representative building types, for each of nine regions. This process results in an AEO2004 forecast deployment of about a total 3 GW of DG electrical generating capacity by 2025, which is only 0.25% of total forecast U.S. capacity. Analyses conducted using both the AEO2003 and AEO2004 versions of NEMS changes the baseline costs and performance characteristics of DG to reflect a world without U.S. Department of Energy (DOE) research into several thermal DG technologies, which is then compared to a case with enhanced technology representative of the successful achievement of DOE research goals. The net difference in 2025 DG penetration is dramatic using the AEO2003 version of NEMS, but much smaller in the AEO2004 version. The significance and

validity of these contradictory results are discussed, and possibilities for improving estimates of commercial U.S. DG potential are explored.

## Introduction

While pressure on the current power system continues to grow, its expansion is constrained and unlikely to keep pace with the developed world's insatiable thirst for electricity. Also, little compelling evidence exists to suggest that improved power quality and reliability is possible under the traditional electricity structure (Siddiqui et al 2005). Consequently, small-scale (100 kW-5 MW) thermal on-site distributed generation (DG) economically driven by combined heat and power (CHP) applications and, in some cases, reliability concerns will likely emerge as a common feature of commercial building energy systems in developed countries over the next two decades. According to one estimate, the share of CHP and renewable energy supply in the European Union is expected to rise to 36% in 2030, up from 31% in 1990 (Scheepers, 2004). In Japan, an over 26% increase in energy consumption in the last decade has made DG an attractive option given the country's heavy dependence on imported energy and its ratification of the Kyoto Protocol (Zhou 2004). In Europe this trend is usually viewed as part of a broader process of electricity market restructuring and deployment of new technologies, especially renewables. However, deployment of DG has not been strongly associated with electricity market restructuring. In the European case, Netherlands, Denmark, and Germany have made significant advances in the quest for distributed energy solutions, while the deregulated markets of the U.K. and Spain have not resulted in exceptional innovation. Active research intended to establish a favourable research and regulatory framework for DG in Europe is underway (Navarro and Diaz 2001, European Commission 2003 and 2004, OTTI 2004). Attempts to learn from comparisons of the disparate existing market structures across Europe have led to policy recommendations for encouraging DG (Uyterlinde et al 2002, Connor and Mitchell 2002). There is no question that all these elements are contributing to a radical rethinking of the traditional paradigm of thermal electricity generation at remote large central stations and its delivery over (often long) transmission and distribution networks. The primary benefit of thermal energy conversion to electricity closer to loads is the opportunity it creates for utilization of otherwise lost waste heat.

Other possible benefits of DG include direct electricity price reduction and stability, improved electricity reliability and quality, emission reductions, and a simple feeling of control and/or independence. Recent improvements in small-scale thermal electricity generation and CHP technologies, resulting in part from U.S. Department of Energy (DOE) research, are enabling a dramatic shift from traditional monopolistic electricity supplier to empowered semi-autonomous self generator. Nonetheless, this transition will require considerable research and confirmation. Because of the significant effect widespread DG adoption could have on the design and operation of building and utility systems, reasonable forecasts of DG penetration are vital, and correctly predicting DG deployment is a worldwide issue.

Somewhat by contrast, in the U.S., deployment of the small-scale thermal generation that is the focus of this paper is generally analyzed independently of renewable generation or the devolution of grid operations. More generally, there is little agreement on what technologies should be included under the DG label (see Pepermans et al. for a broader discussion). For the purposes of this paper, *distributed generation* specifically describes a selected list of technologies currently existent in the commercial module of the U.S. Energy Information Administration's (EIA) National Energy Modeling System (NEMS): small (<5 MW) gas turbines, gas engines, and microturbines.[1] Berkeley Lab uses NEMS to assess the potential of DG in the U.S. commercial sector. Working under the auspices of the Distributed Energy (DE) office of DOE, the goal is to annually estimate the likely beneficial results from DOE research and development (R&D) programmes, as required by the Government Performance and Results Act (GPRA) of 1993. This paper explores how NEMS models DG adoption and how annual model updates can have a significant impact on forecasts of DG penetration, and therefore on the annual GPRA analysis.[2] The focus is on the commercial sector, but other sectors are mentioned, and alternative approaches are discussed.

[1] Gas engines are reciprocating engines fueled by natural gas. Microturbines are small (30-200 kW) turbine engines, also usually fueled by natural gas.

[2] EIA requires that any modified version of NEMS be named differently, to distinguish them from EIA's official AEO Reference Case version. Throughout this paper, NEMS-GPRA is used to refer to the modified version used at Berkeley Lab, while the AEO version of the model is referred to as simply NEMS.

Assessment of DG potential using NEMS is presented in the following order:

- discussion of results
- exploration of the limitations of DG adoption in NEMS
- description of input assumptions and approach
- exposition of the approach to DG adoption in NEMS
- presentation of conclusions

## Results

The results reported here correspond to forecasts of R&D benefit from spending beginning in U.S. Federal fiscal years 2005 and 2006. In keeping with the requirements of GPRA, analysis in progress applies to budgets two years hence, i.e. this work was conducted with tools available in 2003 and 2004. Each year, EIA runs NEMS to produce the Annual Energy Outlook (AEO), and model runs based on the AEO2003 version of NEMS will be referred to as GPRA 2005, while those that use the AEO2004 version of NEMS will be referred to as GPRA 2006. For each analysis, a case is run with the DE R&D programme assumptions, the *programme case*, and a case in which no DE research programme exists, the *baseline case*. This second run is necessary to remove the expected improvements in DG technologies inherently assumed in the *AEO Reference Case*, which presuppose existence of DE programmes.[3] The DE-assigned benefits are measured as the difference between the programme and baseline results. Fortunately, the horizon of the DE office is relatively short-term, with goals not established beyond 2012; that is, most of the programme benefits are likely captured within the NEMS time horizon of 2025.

Note that differences in the results are not only attributable to updates made to the Reference Case version of NEMS, but also to differences between the 2005 and 2006 NEMS-GPRA baseline and programme analysis assumptions. Therefore, an analysis using the GPRA 2005 DE assumptions in the AEO2004 NEMS-GPRA was also performed to control for programme goal changes, i.e. to isolate the effect of changes to NEMS-GPRA. The differences between the AEO2003 and AEO2004 versions of NEMS are discussed later in this paper.

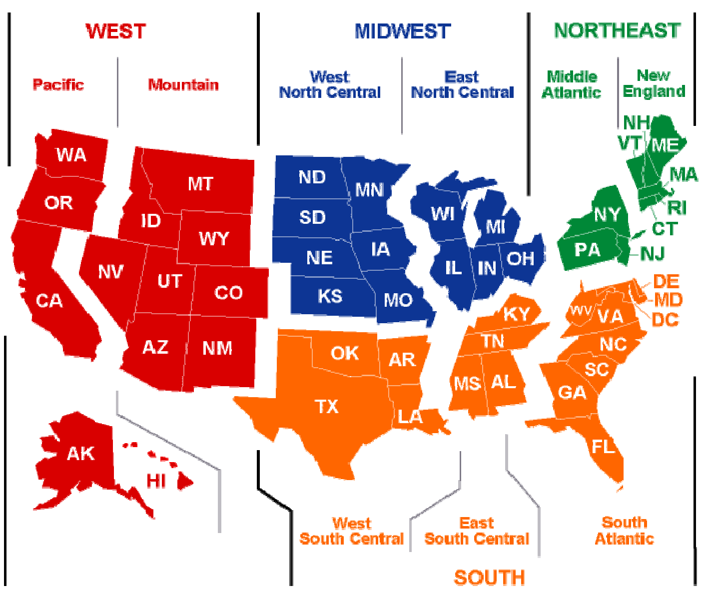


*Figure 1. U.S. Census Regions and Divisions*

[3] The *AEO Reference Case* is standard AEO results which represents EIA's best guess forecast.

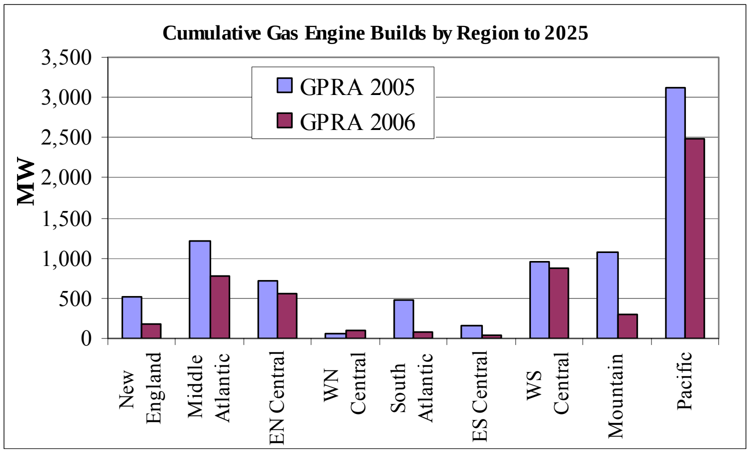


*Figure 2. Gas Engine Capacity*

The overall forecast of DG programme case penetration in the commercial sector has dramatically decreased between the GPRA 2005 and the GPRA 2006 analyses, as can be seen in Figures 2-4. The regions listed in these figures are the 9 U.S. Census Regions, as shown in Figure 1. As is clear, the attractiveness of DG varies considerably across the regions. GPRA 2005 produced approximately 50 GW of cumulative commercial DG by 2025, equivalent to about 4.3% of total U.S. electricity generating capacity, while GPRA 2006 analysis resulted in only 7 GW more DG, or 0.6% of capacity. While both gas engine and gas turbine adoption show significant drops, microturbine adoption fell dramatically. In general, forecast adoption is highest in the Pacific region, where there are areas of high electricity rates. To put this in perspective, the cumulative U.S. capacity increase from these three DG technology sources accounts for 3.9% (GPRA 2005) and 0.7% (GPRA 2006) of total U.S. electricity generating capacity in year 2025.

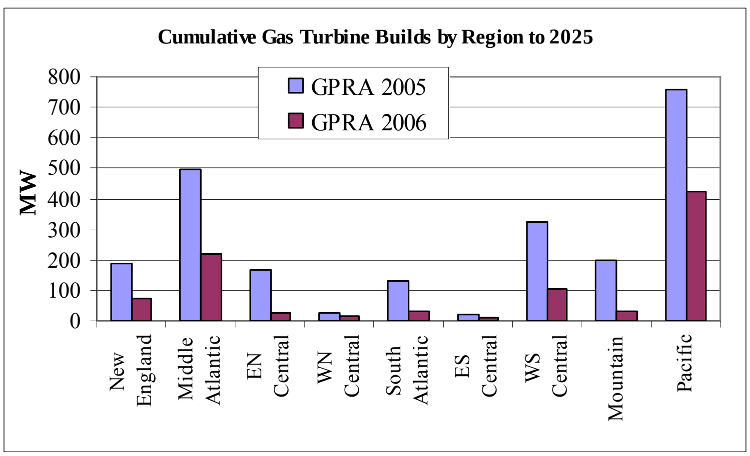


*Figure 3. Gas Turbine Capacity*

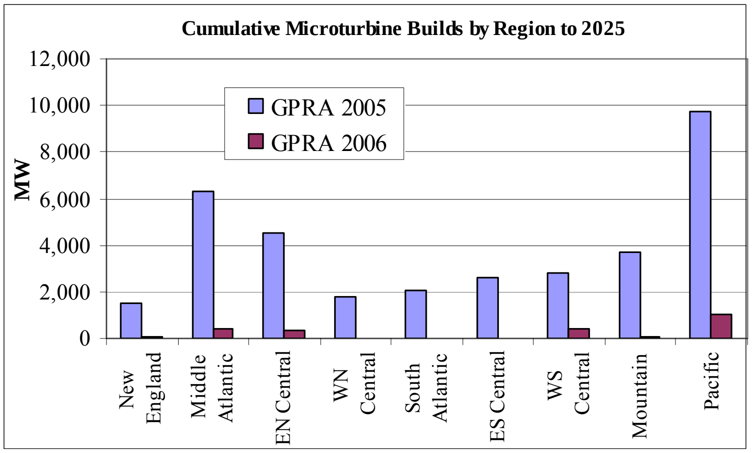


*Figure 4. Microturbine Capacity*

The net changes in total cumulative CHP capacity additions from the GPRA 2005 to GPRA 2006 analysis is also presented in Figure 5. For comparison, total installed CHP capacity in the U.S. today is approximately 73 GW. Note these totals include all CHP, not only DG CHP, and conversely, they do not include DG that is not CHP capable. Again, the GPRA 2006 analysis shows a smaller overall CHP penetration than the GPRA 2005, although the 2006 analysis exhibits a boost earlier in the forecast.

Figure 6 illustrates the change in carbon dioxide emissions between the programme and baselines cases for the same two GPRA analyses. In contrast to the installed capacity, the 2006 analysis shows a greater environmental benefit than the 2005 analysis. This is likely because the 2006 analysis exhibits a stronger DG penetration earlier in the forecast compared with the 2005 analysis, enabling a greater potential for carbon dioxide savings by the end of the forecast.

There are two primary candidate sources of the dramatic inconsistency between the two sets of GPRA results: differences in the assumptions used to represent the various programme goals (as shown in Figures 13-15), and differences in the AEO2003 and AEO2004 Reference Cases (changes made by EIA to NEMS between the two analysis years). In fact, EIA's changes explain most of the drop off, which is illustrated by inputting the GPRA 2005 assumptions into the AEO2004 version of NEMS-GPRA.

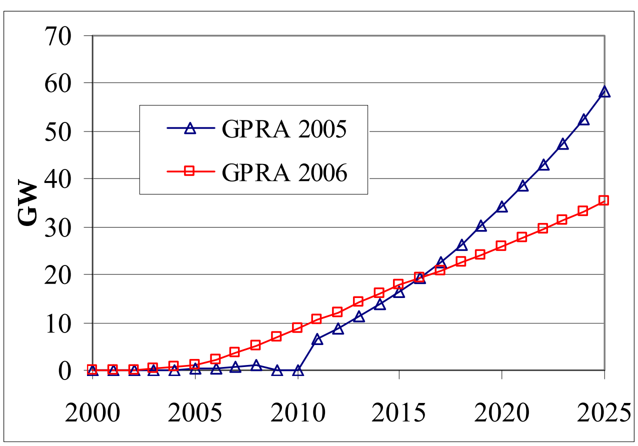


*Figure 5. Change in Total CHP in 2005 and 2006 NEMS-GPRA Analyses*

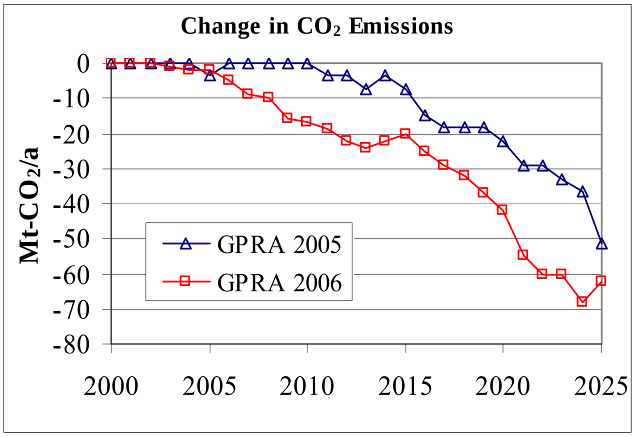


*Figure 6. Comparison of $CO_2$ Emissions in 2005 and 2006 NEMS-GPRA Analyses*

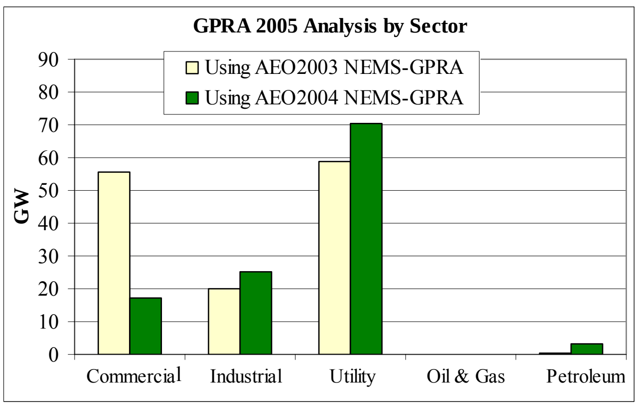


*Figure 7. GPRA 2005 Cumulative DG Capacity Additions by Module, 2005-2025 Using AEO2003 and AEO2004 Versions of NEMS-GPRA*

Figure 7 shows a comparison of the cumulative DG capacity additions from 2005-2025 for the programme case by sector for the GPRA 2005 assumptions input into both the AEO2003 and AEO2004 versions of NEMS-GPRA. That is, the DG cost and performance assumptions for both programme cases shown in Figures 13-15 are equivalent, but the versions of NEMS used are not. Although modest increases in adoption are evident in the industrial and utility sectors, the large reduction in the commercial end-use demand sector drives the overall DG penetration 38.5 GW lower when the AEO2004 NEMS-GPRA is used.

Figures 8 and 9 summarise the results from the GPRA 2005 and GPRA 2006 runs by building type. Annual penetration is forecast by estimating the payback period for each technology, for each of a limited number of representative building types, for each of nine regions. The areas of the pies reflect the overall contribution of each commercial building type to the total U.S. building stock (by floorspace), and the slices show the penetration by the DE technologies into the building type.

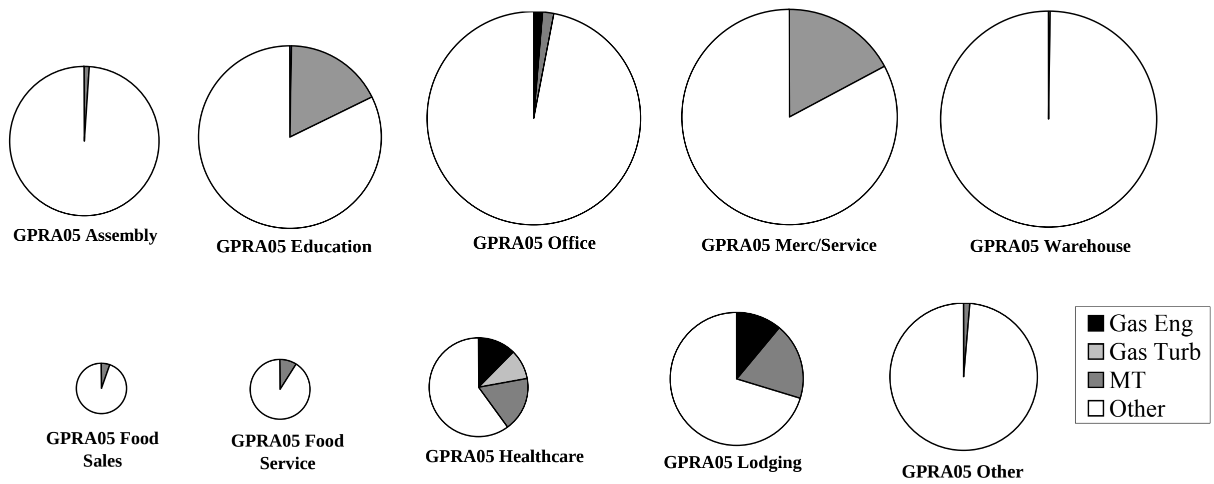


*Figure 8. GPRA 2005 Commercial Module DG Adoption by Building Type*

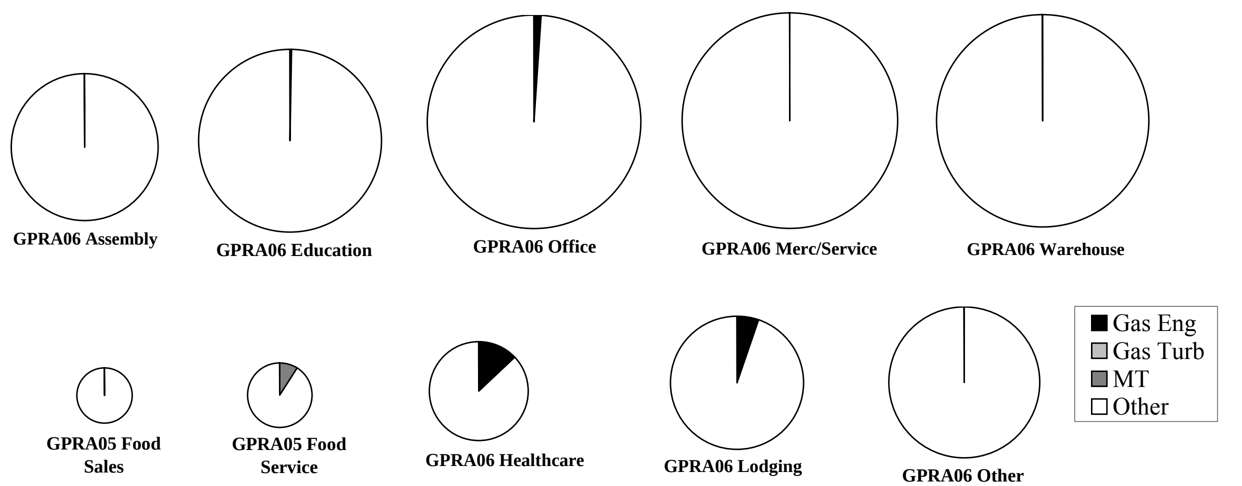


*Figure 9. GPRA 2006 Commercial Module DG Adoption by Building Type*

Comparing Figures 8 and 9, the GPRA 2005 analysis resulted in significant microturbine adoption in the education, mercantile/services, healthcare, and lodging, categories and modest shares of gas engines in the healthcare and lodging categories, with gas turbines penetrating only into the healthcare sector. The GPRA 2006 results essentially report no adoption in any building type except for minimal adoption of gas engines in healthcare and lodging, with equivalent levels of gas turbine adoption in food service.

## NEMS DG Limitations and Findings

A number of factors can help explain the fall in DG adoption between AEO2003 and AEO2004 versions of NEMS.

1. *Natural gas prices are higher in AEO2004*. Figure 10 shows the forecasted wellhead natural gas price from both versions of NEMS. In the early years of the forecast, AEO2004 predicts highly unstable natural gas prices, and the AEO2004 natural gas forecast is an average of 15% higher than the AEO2003 forecast over the last 10 years. These high natural gas prices result in a decline in the heavily natural-gas-dependent technologies, including DG.

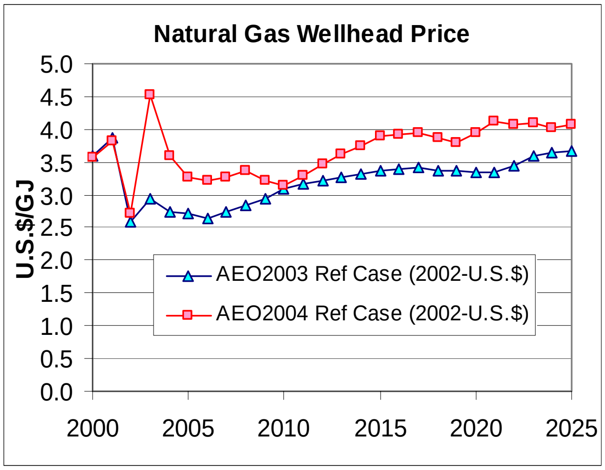


*Figure 10. Comparison of Natural Gas Price in NEMS Reference Case*

2. *A modification to the calculation of tax deductions disfavours DG.* Fuel expenses become deductible, which disfavours the overall economic attractiveness of DG because a customer would no longer be able to deduct the expenses for purchased electricity; however no analysis has been done to determine how much of an impact this change alone has on the overall DG penetration.
3. *NEMS only estimates penetration in new structures*. The retrofit penetration is a fixed fraction of new. The limitation on the number of commercial DG retrofit installations into existing buildings was relaxed from 0.25% to 10% of the existing construction per year in the AEO2004 version of NEMS. Either assumption would be quite arbitrary, making the absence of direct treatment of existing buildings a major handicap. Although this modification is a potential DG benefit for modelling DE programmes, its presence in both the baseline and programme cases may prevent further benefits from being seen. This possibility has not been explored.

Among other limitations inherent in NEMS is that demand charges on commercial electricity bills are not explicitly included in the NEMS payback calculation. Average commercial electricity rates are generally in the range of 6-9 U.S.¢/kWh. This range corresponds to average commercial costs for electricity, but does not consider the effect of commercial demand charges, which tend to favour peak reductions.

A second limitation is there is only a single rated capacity option for each DG technology, which does not allow technologies to be optimised for building sizes. This is a more serious disadvantage than it may seem because the capacity factor of the equipment is fixed and any excess electricity must be sold at the unattractive wholesale price.

Furthermore, DG technologies do not have waste heat driven absorption cooling capabilities. The GPRA05 made a crude assumption that the cooling option lowered paybacks by one year, while the GPRA 2006 analysis does try to incorporate these benefits in a rudimentary way using an exogenous spreadsheet model that estimates any potential reductions in the years to positive payback calculation used in NEMS-GPRA. However, this consideration was added only for gas engines and microturbines. This selective enhancement showed that healthcare, lodging and large offices are the buildings with the greatest absorption cooling potential and the northeast and southwest are the most favourable regions, but in general the penetration of cooling is low. Figure 11 shows an example of the customer payback estimates for cooling enables microturbines in 2008. The addition of cooling only lowers system payback in only three building types, and in only the Pacific region are paybacks low enough for the improvement to really matter.[4] Also, as explained below, adoption is only sensitive to payback over a narrow range.

And lastly, the DG payback calculation is on a knife edge, being highly sensitive to small variations in input parameters, changing from a high to a low value fairly rapidly. In addition, the number of years until a positive cumulative net cash flow is highly dependent on the assumptions for system down payment, which is fixed at 25%. Figure 12 below illustrates the NEMS payback sensitivity to building size. This example is for a lodging building in New England. When the building load is close to 100 percent of the total, the DG payback period is low (1 -5 years). Once the building load is lowered to between 60% and 70% of the total building load, however the payback soars to 28 years.

[4] Note that lower payback periods are better, and only paybacks of less than 10 years are likely to be attractive to potential adopters.

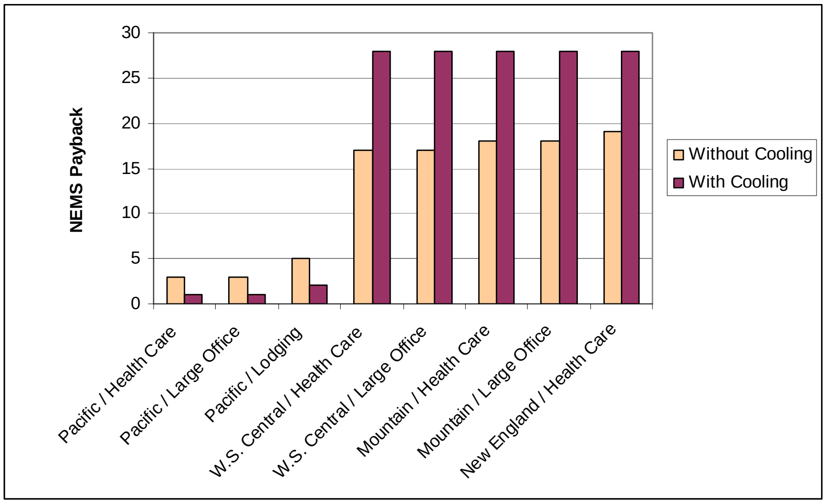


*Figure 11. Example Results from 2008 Microturbine Payback Analysis With and Without Cooling for Most Favourable Buildings and Regions*

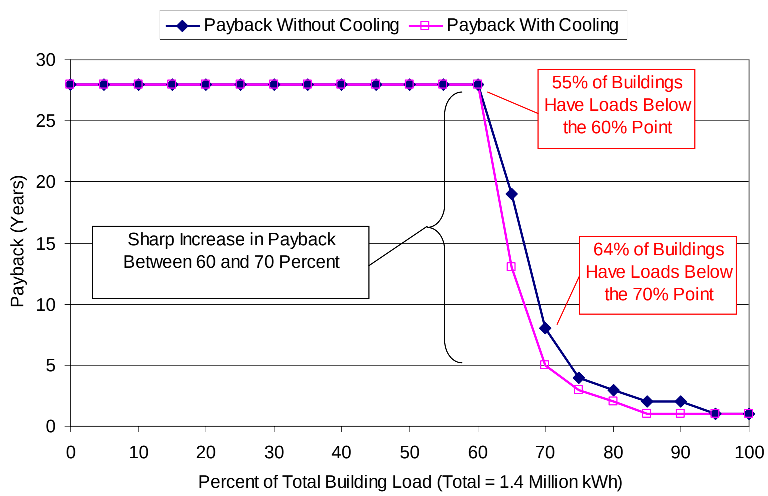


*Figure 12. NEMS Payback as a Function of Building Load (For a Lodging Site in New England)*

## Method

To accommodate the various DG technologies in NEMS-GPRA, Berkeley Lab makes modifications to the commercial, industrial, and utility sectors. The first two are demand sectors, while the utility sector is represented in the Electricity Market Module (see Figure 16 below). Although the analysis presented here includes changes from all three sectors for completeness, the discussion focus is on the commercial sector. Table 1 summarises the representative sizes assumed in NEMS for the technologies included in the DE R&D programme.

In general, the baseline is a 10-year lag of the programme goal assumptions; that is, modifications of costs, electrical efficiency, and combined efficiency for the baseline run assume that a world without the DE R&D programmes would exhibit equivalent progress 10 years later. The programme case necessarily tailors the DE R&D goals to the practical limitations of NEMS. The costs[5], electrical efficiency, and combined efficiency of the target technologies are modified to reflect the DE R&D goals.

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[5] All monetary values used in this paper are in U.S.$ of the year noted. The conversion from year 2003 U.S. dollars to EURO is performed assuming 1 U.S. dollar is equivalent to 0.85 EURO. Source: Oanda currency converter, http://www.oanda.com/convert/classic?user=convertme&lang=en

**Table 1. Summary of Commercial DE Technology Size Representation**

| Technology Type | Representative Size in NEMS |
|---|---|
| Gas Turbine | 1 MW |
| Microturbine | 100 kW |
| Gas Engine | 200 kW |

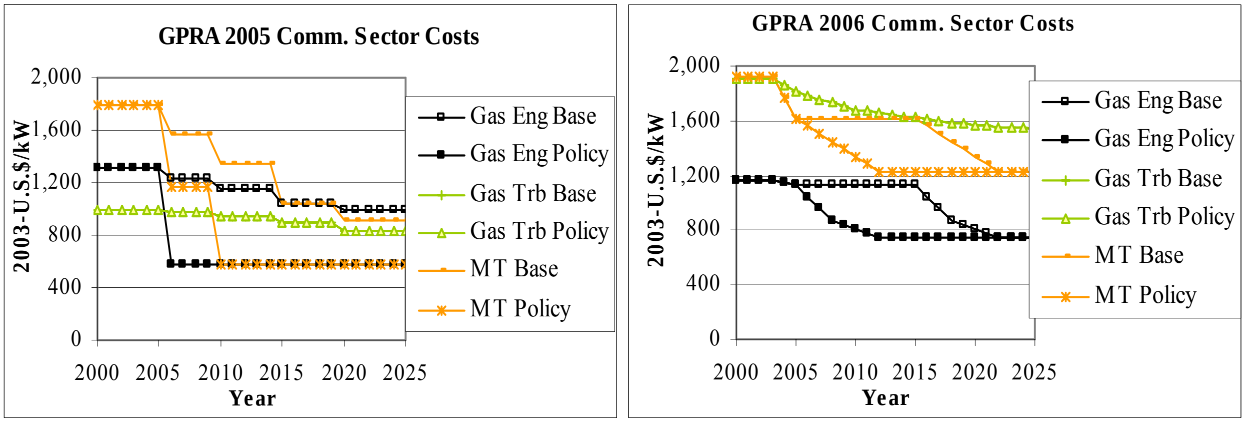



*Figure 13. GPRA 2005 and GPRA 2006 Commercial Costs*

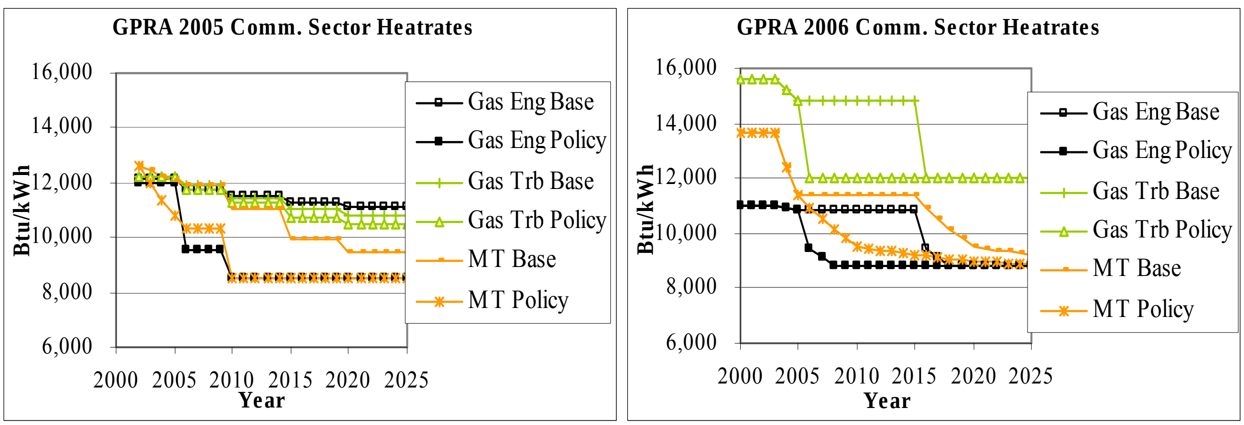



*Figure 14. GPRA 2005 and GPRA 2006 Commercial Heatrates*

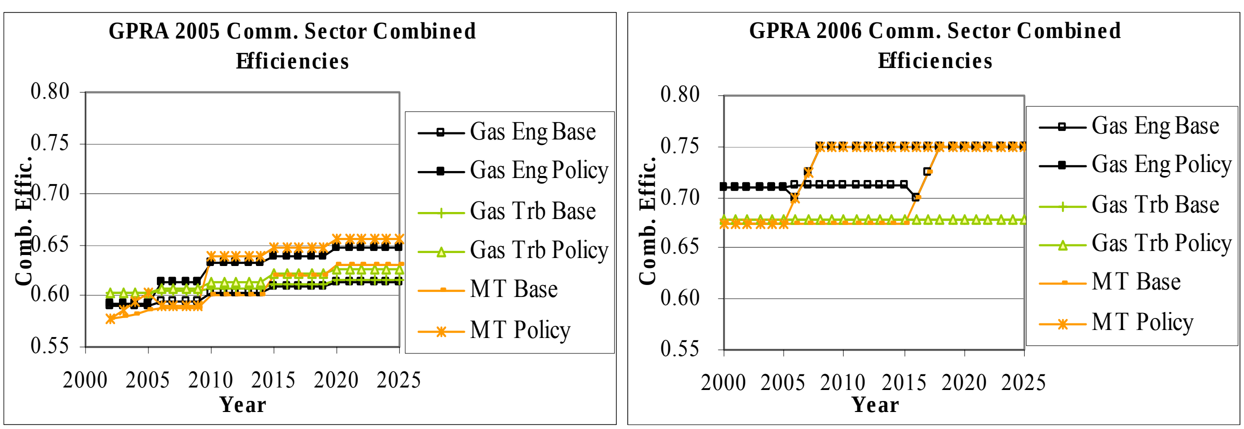



*Figure 15. GPRA 2005 and GPRA 2006 Commercial Combined Efficiencies*

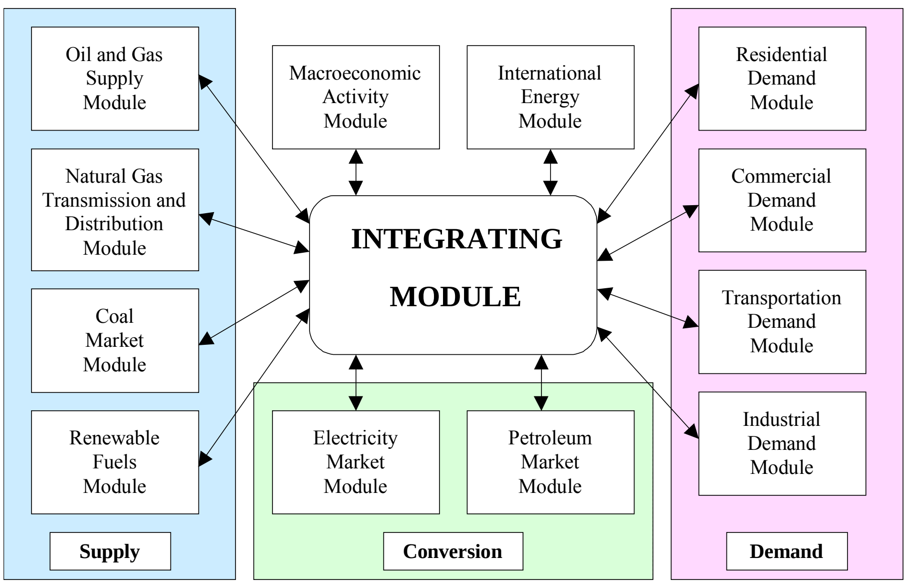
Figures 13, 14, and 15 represent the baseline and programme commercial DG technology assumptions for cost, electrical efficiency, and combined efficiency for both the 2005 and 2006 analyses. Remember that the baseline estimates are forecasts made on the assumption that DE R&D does not take place while the programme estimates assume the targets of DE R&D are achieved. All estimates are a mix of expert opinion, conjecture, and optimism. The rules of GPRA do not allow consideration of uncertainty, so only the two deterministic cases are modelled. Both GPRA years are shown to demonstrate the significant differences in the assumptions. In 2005, Berkeley Lab used professional judgement to translate the sparsely available programme goals of the DE office, while in 2006, more explicit assumptions and direction were provided.

## The NEMS Approach to DG Adoption

### *The National Energy Modeling System*

NEMS is a large multi-sectoral U.S. energy model designed to forecast 20 years out the behaviour of energy markets and their interactions with the U.S. economy, and it produces the influential AEO. NEMS relies on fairly transparent assumptions due to the exposure and scrutiny each AEO receives, but the model is huge and many of its operations are opaque at best. On the other hand, because its scale allows it to measure the interactions between the various energy supply and demand sectors and the economy as a whole, NEMS potentially offers a comprehensive picture of the possible benefits results of technology research programmes.

Figure 16 shows how NEMS is structured (EIA 2003).




source: Adapted from Energy Information Administration. 2003. *The National Energy Modeling System: An Overview 2003.* DOE/EIA-0581(2003). March. Washington, DC.

*Figure 16. Overview of NEMS Modelling Structure*

Each of the demand modules uses nine U.S. Census Divisions shown in Figure 1, while electricity supply is represented by 13 regions, and other regional specifications are used elsewhere. Each module is independent of the others, and the integrating module orchestrates iteration towards the overall solution, which represents a partial equilibrium for the entire U.S. energy sector. While description here is limited to the Commercial Demand Module, DG is currently represented in the Residential Demand Module, the Electricity Market Module, the Industrial Demand Module, and to a lesser extent elsewhere in the Oil and Gas Supply Module, and the Petroleum Market Module. Additionally, customer-sited renewable technologies appear in the Renewable Fuels Module. This scatter, together with NEMS's diversity, makes an assessment of DG's overall potential a major challenge. For example, incorporating waste heat driven absorption cooling capabilities into NEMS would require modifications to at least two of the demand modules and to incorporate DG applications in non-represented sectors would require modifications to each module individually. DG is a disruptive technology, which straddles the demand, energy conversion, and supply corners of NEMS,

## *Commercial Building Representation in NEMS*

The commercial sector is divided into 11 building types: assembly, education, food sales, food services, healthcare (inpatient), lodging, large offices (> 4,645 $m^2$ including outpatient medical facilities of the same size), small offices (≤ 4,645 $m^2$ including outpatient facilities), mercantile and service, warehouse, and other, i.e., laboratories, etc. Within the building types, NEMS considers 10 different energy consuming service classes: space heating, space cooling, ventilation, water heating, lighting, cooking, refrigeration, office equipment (personal computers and everything other than personal computers), and other. Other input characteristics include building shell efficiency for new and existing buildings, age class of the building, floorspace sorted by each of the 9 U.S. Census Divisions, energy use intensities, building type, and fuels. These parameters characterise an approximate distribution of buildings in the U.S. that is used to determine energy needs throughout the forecast, and to evaluate DG potential (EIA 2004)

## *DG Treatment in the Commercial Demand Module*

Commercial sector DG penetration is determined by a submodule using a cash-flow analysis that evaluates the economic attractiveness of a DG system in a given building, in a given region, in a given year, and adopts if economically attractive, subject to penetration limits. The submodule receives electricity and natural gas prices from the NEMS supply-side modules at the Census Division level. Commercial building starts and stocks are also passed into the module. Although NEMS accounts for both DG penetrations to new construction as well as retrofits to existing construction, the submodule analysis focuses on adoption into new construction, and penetration to the existing stock is assumed proportional. The NEMS documentation justifies this approach by asserting that estimating retrofit costs is too complex to be generalised (Boedecker et al. 2000). Caps are set on DG penetration in both new and existing buildings, but the submodule ensures minimal DG installations in the existing stock by imposing a much stricter limit (as explained below). Available housing and building starts and stock together with the results from the cash flow analysis are passed into the penetration function, which uses a logistic curve to determine adoption. The submodule then tallies up the amount of DG installed and assumes any excess waste heat available to supply water heating or space heating demand is effectively applied. As discussed above, there is no consideration of thermally activated cooling. The average electricity and hot water consumption is used to determine any need that DG cannot offset. Additionally, the submodule checks whether excess DG generation is available for sales back to the grid, and if so, passes them back to the Electricity Market Module, while natural gas requirements for DG fuel are added to commercial sector gas consumption (LaCommare et al 2003).

The general DG goal pursued by the DE office is that 20 percent of all new generating capacity additions be from DG sources by 2020. This DG goal represents electricity-generating capacity only, and does not include large-scale CHP capacity forecasts, which are also represented by the DE programme. Berkeley Lab interprets the DE goal to imply approximately 28 GW of new DG capacity must be installed by 2020. The AEO2004 forecasts 235 GW of required new capacity from electric generators and cogenerators from 2004-2020. Of this, only 8 GW (3% of the total new capacity) is forecasted to come from large-scale[6] utility-owned DG with an additional 1 GW of DER from small-scale residential and commercial sector installations, for a total of 9 GW.

Clearly, commercial DG with CHP represents only a tiny share of the overall CHP in the AEO2004 forecast, the majority of which is comprised of large-scale industrial gas turbines. In fact, the total installed CHP capacity by 2025 is predicted to be 30 GW (9 GW of which represent additions from 2006-2025), with 29 GW from the industrial sector and the remaining 1 GW from the commercial sector. Although larger industrial penetration is likely to help attain the DE goal, CHP potential in the commercial sector is being overlooked (OnSite Sycom Energy 2000).

The commercial module has 10 different DG technologies, as shown in Table 2. The three DE office technologies are shown in italics.

[6] Large-sce DG refers to generators ≥ 1 MW in size. NEMS defines two DG technologies of this type: a 1-MW peak load unit and a 2-MW base load utility-owned unit.

**Table 2. Summary of NEMS Commercial DG Technology Types**

| Technology Name | Lifetime (years) | Capacity Factor (%) | Conversion Efficiency | | Equipment Cost (1999-$/kW) | | Size (kW) |
|---|---|---|---|---|---|---|---|
| | | | 2000 | 2020 | 2000 | 2020 | |
| Solar Photovoltaic | 30 | 100 | 14 | 22 | 7370 | 2872 | 10 |
| Fuel Cell | 20 | 86 | 36 | 50 | 3674 | 1433 | 200 |
| *Gas Engine* | *20* | *86* | *28* | *31* | *1390* | *990* | *200* |
| *Gas Turbine* | *20* | *86* | *22* | *28* | *1600* | *1340* | *1000* |
| *Microturbine* | *20* | *86* | *26* | *36* | *1970* | *915* | *100* |
| Conventional Coal | 20 | 86 | 30 | 30 | | | 200 |
| Conventional MSW | 20 | 86 | 24 | 24 | | | 200 |
| Conventional Oil | 20 | 86 | 31 | 31 | 1390 | 990 | 200 |
| Biomass | 20 | 86 | 24 | 24 | | | 1500 |
| Hydroelectric | 20 | 86 | 29 | 29 | | | 1000 |

## *DG Payback Approach*

DG technologies in NEMS are adopted annually by each of the 11 commercial building types based on the number of years required to achieve a positive cumulative net cash flow. The payback calculation differs from the traditional definition of simple payback to account for financing options. In the *traditional* simple payback, all system capital costs are paid for in full in the first year of the investment and there is no discounting of future cash flows. Net annual savings from the investment are accumulated until the initial investment cost is recovered. In the NEMS payback approach, the system investment costs are financed over 15 years at an 8.5% interest rate with a 25% down payment in the first year. The net cash flow in subsequent years includes interest and principal payments for financing, and the annual net cash flows are added to the initial down payment until a positive cumulative net cash flow occurs. In general, the NEMS payback period will be shorter than the traditional payback.

Figure 17 below illustrates the difference between traditional payback and the NEMS payback calculation. This simple example shows a total system cost of US$10,000, where annual savings from operation of the DG system (the net of savings from electricity and heat load offsets, tax deductions, fuel costs, and O&M costs) total $2,000 a year. The traditional payback has a higher up-front cost (100% of the system cost) but the annual savings are the full $2,000, resulting in a payback in the 6th year of the cashflow. The NEMS payback has a smaller up-front payment (25% of the system cost) but annual net savings are less, since the financing payments must be accounted for (approximately $875/year based on the loan terms described above). In this example, the NEMS payback occurs between the 3rd and 4th year.

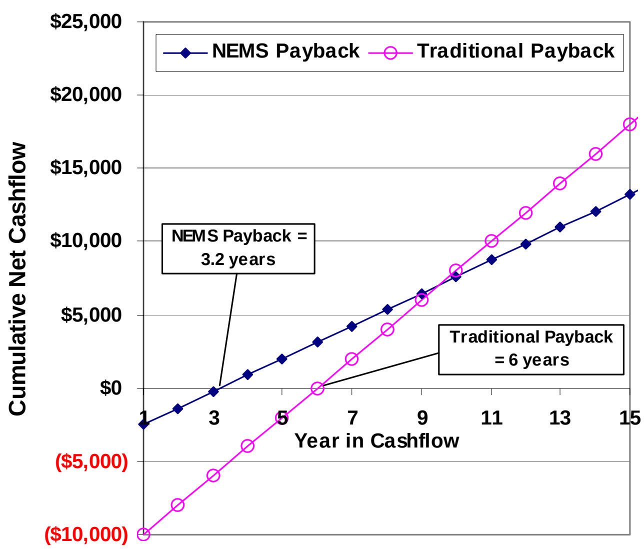



*Figure 17. NEMS Payback versus Traditional Payback*

### *NEMS DG Adoption Logic*

For every year in the NEMS forecast analysis, a given technology payback is calculated for the 99 different combinations of 11 building types and 9 census divisions. The payback value determines the total capacity installations for each year based on defined market penetration curves, shown in Figure 18. The penetration values correspond to a share of the new building market, while the existing building market automatically adopts the lesser of 0.5% of the existing construction or 2% of what the new building market does.

For example, if the payback is estimated as 3.2 years, as in Figure 17, then the relevant curve in Figure 18 is the 3-year line. For each year of the forecast, a given market share will adopt. In 2015, 10% of new buildings of this type in this region will adopt this technology and 0.5% as many existing building types will retrofit.

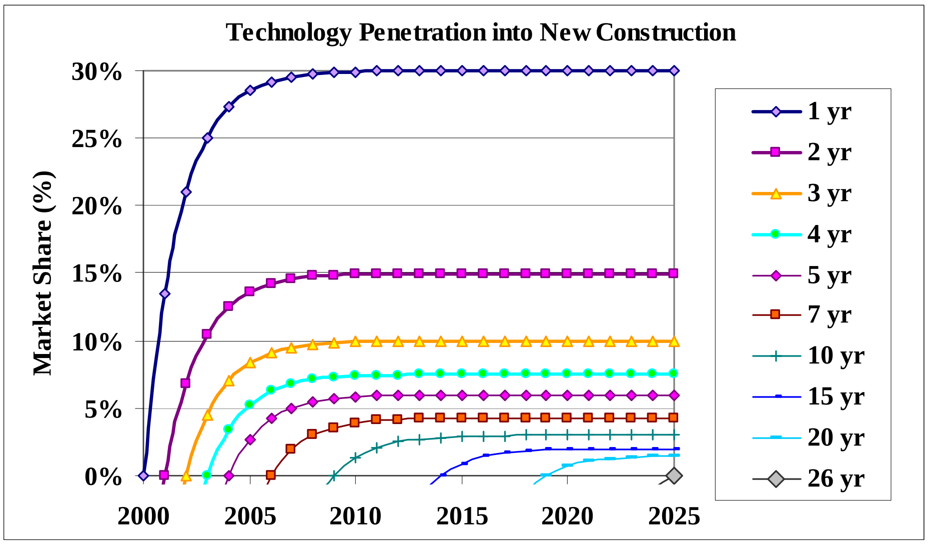



*Figure 18. Market Penetration Curves for Various Payback Periods*

Capacity additions therefore depend on both the years to positive payback and the shape of the penetration curves. Note the rapid rate at which the maximum penetration of a technology falls off as a function of the years to payback.

## Conclusions

This paper explores the pitfalls experienced in the annual modelling of DE programme goals using NEMS, as is required by GPRA. Two DE analyses are presented, GPRA 2005 and GPRA 2006, using two different versions of the NEMS model, based on the versions used to prepare AEO2003 and AEO2004.

In general, the overall DG penetration exhibits a dramatic dropoff in the GPRA 2006 analysis compared to the GPRA 2005 analysis. Although significant differences exist in the baseline and programme cases of these two analyses, Berkeley Lab determined that differences in the Reference Case versions of the model, not differences in the assumptions uses in the 2005 and 2006 analyses, likely explain significant decrease of DG penetration. It is still unknown exactly what changed in the model to produce such a strong effect.

Some potential factors include:

- a higher natural gas price forecast in the AEO2004, making gas-fired DG technologies economically less attractive,
- a change to the commercial DG tax treatment that accounts for increased revenue from avoided purchased electricity , which increases a customer's tax burden and makes DG less attractive, and
- a relaxation of the cap to existing building retrofit DG purchases from 0.5% to 10% of penetration into existing construction.

These limitations coupled with a number of pre-existing NEMS constraints that include only a single size for each DG technology, no explicit consideration of commercial sector demand charges, and the sensitivity of the customer payback on commercial DG adoption all make modelling DG benefits in NEMS challenging. Further development efforts are needed to develop the credible forecast of disruptive DG technology adoption that are needed to craft effective policies and R&D programmes that will enable the coming transformation of the power system to a dispersed paradigm.

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## Glossary

| | |
|---|---|
| AEO | Annual Energy Outlook |
| CHP | combined heat and power |
| DE | U.S. DOE Distributed Energy office |
| DG | distributed generation |
| DOE | U.S. Department of Energy |
| EIA | Energy Information Administration |
| GPRA | Government Performance and Results Act |
| NEMS | National Energy Modeling System |
| O&M | operations and maintenance cost |
| R&D | research and development |

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