MODERNIZING AND USING THE PROJECT CONTROL DOCUMENT

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ABSTRACT

The Project Control Document [PCD] is a management tool. It is a total presentation of all the key project characteristics and decisions along with a codification of the rationale, inter-relationships and impacts of each attribute. When the PCD is augmented by an integrated technical, economic, and financial computer model which incorporates structural, performance and cost characteristics, an integrated system is created which rapidly identifies and quantifies the cascading impact of decisions and changes as a project evolves. This integrated system is the Modernized Project Control Document [MPCD]. The ramifications of the project's modifications and changes can be evaluated as the project becomes better defined and developed. Decisions can be tested (from fairly early stages) using investment criteria and sensitivity analysis as supplemental criteria for waste management system optimization. Violation of legal, public, business or financing requirements and preferences are immediately flagged so that remedial action and changes in project definition can be made.

This paper presents starting assumptions for some of the key, hard-to-analyze areas in addition to the typical information in the MPCD.

INTRODUCTION

Developing a resource recovery facility is a long, complex process which is repeatedly subject to unexpected outside influences. The Project Control Document (PCD) is a valuable tool that helps management through this process because it permits the rapid, quantitative assessment of the impact of changes, suggestions, and alternatives.

The traditional PCD can be modernized with the aid of computers by reducing the information to mathematical models that are linked and forced to interact within the framework of an integrated computer system. Both the PCD narrative and the derived computer model are then used for management control during the various stages of the project. While computers are commonly used to analyze portions of projects, the computer model that modernizes the PCD is an integrated system that takes into account technical performance, waste supply, cost, and business relationships in a single system. The Modernized Project Control Document [MPCD] also recognizes technical, environmental, financial, business, public preference and institutional considerations that constrain a project and, during the early planning stage, provides the ability to evaluate changes using the ultimate common criterion—money. The MPCD is on hand to evaluate "what ifs" and other events which may affect the project during its development or even after its conclusion.

MODERNIZED PROJECT CONTROL DOCUMENT

The MPCD consists of two major parts: a narrative and an integrated computer model. The narrative describes the complete project in words and pictures and, like the computer model, becomes more detailed as the project progresses. The model quantitatively merges the technical knowledge and financial aspects (including business relationships and constraints as well as economics) of the project defined in the narrative. It provides a comprehensive means of comparing expectations and reality.

The Narrative

A well constructed MPCD narrative contains sections relating to each of the major aspects of a project. The following paragraphs provide a narrative outline for the text of an MPCD.

The Characteristics Section describes the Municipal Solid Waste (MSW) stream to be managed. Definition includes potential waste sources, locations, quantities and qualities. Eventually, business principles for a sponsor-acceptable contract will be replaced by letters of intent and waste supply agreements.

The Available Disposal Methods Section defines where waste is currently being collected and disposed; the cost and longevity of the current disposal point; other area management alternatives, including landfills and resource recovery plants being developed; and source reduction and recycling efforts.

The Alternatives Section provides descriptions of the differing methods that might be used to meet the area's waste management objectives. The comprehensive list is rapidly reduced by first eliminating alternatives which are unacceptable for any reason and by performing screening analyses until a limited number of apparently feasible alternatives for further development emerge. This section is extremely important in a public environment where basic decisions are revisited long after they are made. Ready access to the reason for a prior rejection can show that the process was proper and the alternative remains unattractive.

The Facility Section describes the disposal alternative and includes siting considerations along with other relevant considerations such as access, public utilities availability, geotechnic requirements, zoning, development, and cost. This section forms the basis for an Environmental Impact Statement, permit submittals and facility procurement documents.

The Disposal Section examines the requirements for and availability of feasible residuals management alternatives. It addresses the disposal of residues, including ash and unprocessibles. This section could be the start of another MPCD if a separate ash disposal project is initiated.

The Public Participation Section identifies how the public will provide input into the project, establishes preferences, provides feed-back on how concerns are being addressed and serves as a mandatory check that an acceptable solid waste management project is being pursued.

The Product Sales Section covers steam, electricity, and recycled materials marketing. For each product, quantity, quality, delivery requirements, price, potential purchasers and business deals are considered.

The Regulatory and Planning Section recognizes the legal and regulatory constraints on the project and identifies required approvals, relevant agencies, and local planning requirements. Key technical and philosophical information is accumulated and permit filings and correspondence are eventually added.

The Schedule Section is necessary to ensure project coordination and that deadlines are met. Key "go/no go" decision points and criteria are defined.

The Business Plan Section lays out how the facility will be bought and the risks and guarantees to be provided by the community and supplier.

In the Financial Plan Section, the financing and business criteria that constrain the project are defined.

The Project Economics Section brings together data, from the balance of the document, for evaluation on a common basis—money. The economic performance criteria for the project are established and results from the computer model described later are provided to determine probable economic feasibility.

It is obvious from the information listed under the headings of the MPCD Narrative that, at least in the initial stages, very little precise and accurate information will be available. In the initial stages, statements of legal requirements, policy preferences, public questions indicating a lack of knowledge, or lack of decision, are as important to the control and development of the project as final resolution of these concerns.

The Computer Model

The concepts embodied in the narrative can be expressed as mathematical models and incorporated into a technical (including environmental), economic and financial computer model that integrates and modernizes the PCD. The computer model begins at a technical level (using the information on solid waste supply, utilities, and equipment characteristics) to define performance expectations for selected operating conditions.

Environmental impacts and health risks are estimated and compared to standards and public opinion. Engineering economics are developed and modeled. All these assessments are brought together in the financial analysis which uses performance, capital and operating cost estimates and inflation and interest rate assumptions to develop debt requirements and long term economics for the assumed procurement approach and business deal.

The initial MPCD computer model uses plug numbers and representative facility performance models to provide initial estimates. As the project evolves, and the MPCD narrative is revised or confirmed by project-specific negotiations and investigations, the computer model is concurrently refined to provide coordinated real-time monitoring of the project.

The center of the MPCD computer model is a multiyear proforma accrual statement. Meaningful output from the proforma accrual statement requires technical input from process performance models. These same process performance models generate estimates of environmental impacts and required consumables. This paper focuses on the development of a generic MPCD computer model.[1]

Technical Models

An analysis which considers the waste collection schedule, the facility configuration, the major component quality and capacities, the energy buyer's characteristics and the facility's maintenance plans is required to effectively predict the amount of waste that can be incinerated by a specific facility (Rigo, 1982; Rigo and Davis, 1984) and the amount of steam that can be used to generate electricity. For usual situations, waste bypass will be minimal as long as the average annual delivery rate is less than 80–85% of the facility's nameplate capacity and storage is provided for 3–4 days of burning capacity. Due to typical turbine generator reliability, it is reasonable to assume that at least 99% of the steam raised will be used to generate electricity except in years when the turbine is scheduled for open shell inspections and repair. For such years, using $^{11}/_{12}$ of the annual steam production to generate electricity has proven to be a reasonable assumption.

Once waste is processed, the amount of useful energy recovered depends on two things: the facility type and the required energy product characteristics. The best way to determine energy production rates is to perform a complete engineering system analysis (a step in the development of the facility narrative). Table 1 is a typical boiler heat balance for a 450 TPD mass burning water wall incinerator which produces turbine grade steam. The calculations are conventional and can be found in standard texts (Zerban & Nye, 1964; Combustion Engineering, 1978). For screening purposes, the ultimate fuel analysis can be based on typical moisture and ash free [MAF] characteristics and radiation losses are calculated as double the value estimated using the American Boiler Manufacturer's Association curve (ASME, 1968).

The emission factors shown in Table 2 assume a stoichiometric release of sulfur and chlorine as well as representative values for the nonconservative pollutants. The emission factors can be tailored for specific technology selections for conventional pollutants (Rigo, et al., 1982) and the EPA toxic equivalents and control efficiency for dioxin and furan emissions (Rigo and Markiewicz, 1987).

The fire-side flows developed using the boiler balance can be coupled with a screening level dispersion model such as that proposed by Golomb, et al. (1983) and by using the analytic form of the Pasquill dispersion coefficients suggested by Green, et al. (1980) to rapidly estimate maximum ground level impacts which can be compared to ambient air quality criteria as shown in Table 3. In Table 4, the screening analysis is extended to a comparison of trace element impacts to various metrics, while the carcinogenic risk is calculated using Carcinogenic Assessment Group (USEPA, 1985) methodologies and potency slopes.

Economic and Financial Models

Table 5 is a representative proforma accrual statement which has been generated for a hypothetical 2400 tons per day [TPD_7][2] nameplate capacity waste-to-energy plant that is publicly owned and operated. The facility sells electricity generated from processing an

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[1] The outputs shown in this paper were all generated using a 20/20 Spread Sheet Program on a DEC PRO 380 minicomputer. We are not aware of any reason why the algorithms can not be adapted for use on other spread sheet systems and microcomputers. The final tailored MPCD computer model for the Southeast Resource Recovery Facility in Long Beach, California takes about 20 min to run.

[2] The subscript denotes that the value is for a 7-day calendar week as opposed to a 5 or some other work-day week.

TABLE 1 TYPICAL BOILER HEAT BALANCE

```
                                          Total Excess Air                     65% Fraction of Ash to Boiler                   10%
                                          fraction air under grate             67% Grate Ash discharge Temperature             750
                                          weight flue gas recirculation        10% UBC in Fly ash                               8%
                                          Misc. Steam Leaks & Losses          1.5% UBC in Bottom Ash                            3%
                                          Blow Down                           2.0% Weight of Residue                         23.2%
****** ULTIMATE ANALYSIS ******           deNOx Carrier air--% of Theo.       4.2% Average temperature of residue              505
ASH,  % by weight                   22.40 General Air leakage-% of Theo.      4.1% Fraction Combustibles Burnded            98.41%
C,    % by weight                   26.78 Main Steam Flow,     lb/hr        155000
H2,   % by weight                    3.84 S.H. outlet press.. psig             617 ***MOLECULAR WEIGHTS***
S,    % by weight                    0.11 S.H. outlet temp..  deg F            752 Hydrochloric Acid                         40.97
02,   % by weight                   20.21 Feedwater press..   psig             800 Carbon (C)                                12.01
N2,   % by weight                    0.41 Feedwater temp..    deg F            332 Hydrogen (H2)                              2.02
H20,  % by weight                   26.00 Reheater steam flow, lb/hr             0 Sulfur (S)                                32.07
Cl2,  % by weight                    0.24 Rehtr. outlet press..psig              0 Oxygen (0)                                32.00
HHV,  Btu/lb                         4799 Rehtr. outlet temp.. deg F             0 Nitrogen (N2)                             28.02
Excess Air Supplied by Fans, %       60.9 Rehtr. inlet press.. psig              0 Water (H20)                               18.02
Unburned Comb. loss, %               1.62 Rehtr. inlet temp..  deg F             0 Chlorine (CL2)                            79.92
UBC in residue , %                   3.52 Drum press..      psig               725 Carbon Dioxide (C02)                      44.01
Gas temp lvg econimizer, F            476 Drum temp.(sat.)  deg F              509 Sulfur Dioxide (S02)                      64.07
Gas temp lvg air heater, F            476 S.H.outlet enthalpy, Btu/lb      1379.90 Carbon Monoxide (C0)                      28.01
Ambient Air Temp., F                   60 F.W.inlet enthalpy,  Btu/lb       300.90 STAND. AIR COMPOSITION
Radiation loss, %                   0.351 Rehtr. out enthalpy, Btu/lb         0.00 02,  % by volume                          20.99
Sensible heat in residue, %         0.430 Rehtr. in. enthalpy, Btu/lb         0.00 N2,  % by volume                          79.01
Unaccounted for loss, %             0.545 Drum sat vapor enth.,Btu/lb      1200.20 H20, % by weight                           1.30
U.F.A. Steam Heater Rise, F            98 Drum sat liq. enth., Btu/lb       499.00 Molecular weight dry air                  28.86
Reference Temperature                  60
                                                                                   ***ADJUSTMENTS TO HHV FOR DIFFERING CONDITIONS***
MOLES/100 lbs FUEL actually burned                                                 Sensible Heat in Fuel        Btu/lb=        0.0
adjustment for UBC as proportion of                                                Sensible Heat in Air         Btu/lb=        0.0
heat lost to unburned combustibles        ***PARTIAL PRESSURES, PSIG***            Compression Heat             Btu/lb=        7.3
                                                                                   Steam Air Heater Input       Btu/lb=       86.3
C   =                             2.19372 P(C02) =                           1.364 Effective HHV                Btu/lb=       4892
H2  =                             1.87124 P(H20) =                           2.318        Dry gas loss, %            =        12.8
S   =                             0.00336 P(S02) =                           0.002        Water from fuel loss, % =           15.6
02  =                             0.62148                                                 Moist. in air loss, %      =         0.3
N2  =                             0.01457 Percent by Volume (Orsat)                       Total losses, %            =        31.7
H20 =                             1.44284 % C02 =                            11.02 Actual Boiler Efficiency, %       =        68.3
Cl  =                             0.00587 % 02  =                             8.71 Eq. Eff.--Adjusted to As-fired HHV        69.7%
                                          PPM S02                              169 ***BOILER OUTPUT***
***THERO. 02 REQ'D, MOL/100 # FUEL***                                              Feed Water Flow                  =       158096
                                          ***FLUE GAS WEIGHTS, lb gas/lb fuel*** Blowdown flow, lb/hr             =         3096
For: C + 02  = C02                2.19372 Lb. HCl/lb fuel =                  0.002 High press. h/out-h/in, Btu/lb   =         1079
For: 2H2 + 02= H20                0.93562 Lb. C02/lb fuel =                  0.965 Reheater : h/out-h/in, Btu/lb    =            0
For: S + 02  = S02                0.00336 Lb. H20/lb fuel =                  0.672 Blowdown : h/out-h/in, Btu/lb    =          198
For available 02 & Cl            -0.62735 Lb. S02/lb fuel =                  0.002 High press. duty, Btu/hour       =   1.6724e+08
Theor mols 02 to be supplied      2.50534 Lb. N2/lb fuel =                   4.476 Reheater duty, Btu/hour          =            0
                                          Lb. 02/lb fuel =                   0.555 Blowdown duty, Btu/hour          =      613,221
Wet Theo. Air, # air/# fuel       3.48892 Lb. Dry flu gas/# fuel burnd       6.001 Total Boiler Output, Btu/hour    =   1.6786e+08
Mols dry air./ mols 02 =          4.76417 Lb. Wet flu gas/# fuel burnd       6.673
Moles Dry air /lb fuel =          0.20200 Flue gas molecular weight =        28.23 *****BOILER FUEL. AIR, & FLUE GAS FLOW RATES*****
Lb. dry air req'd/lb fuel =       5.82891 H20 in gas, % by weight =          10.07 Fuel flow rate--tons per day     =          602
Lb. H20 in air/lb fuel =          0.07578                                          Fuel heat input, Btu/hr          =    245635056
Lb. Std. Air req'd/lb fuel =      5.90468                                          Fuel flow rate. lb/hr            =       50,208
                                                          Fd=      9540            Total air to boilers, lb/hr      =      296,464
***FLUE GAS ANALYSIS:***                                  Fc=      1791            Flue gas leaving boiler system   =      335,050
Moles HCl/ lb fuel =              0.00006                 Fo=      1.12            Air leakage,lb/hr                =        7,125
Moles C02/ lb fuel =              0.02194    Lb-steam/Lb-fuel=     3.09            Thermal DeNox Carrier Air        =        7,429
Moles H20/ lb fuel =              0.03729                                          undergrate air flow              =      188,880
Moles S02/ lb fuel =              0.00003                                          overfire air flow                =       93,030
Moles N2 / lb fuel =              0.15975                                          Flue gas recirculation           =       33,505
Moles 02 / lb fuel =              0.01735                                          Flue gas leaving economizer      =      368,556
Tot. Mols Flue gas/lb fuel =      0.23641                                          Total residue generation rate, lb/hr     11,658
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TABLE 2 TYPICAL AIR POLLUTION CONTROL CALCULATIONS

```
PRESSURE INCREASE ACROSS FAN          15
BAG HOUSE HEAT LOSS                 0.5%

DUCT PRESSURE--"H20                -8.00
PLANT ALTITUDE--FT                     3
VOLUME OF MOISTURE                 15.8%
SCRUBBER OUTLET TEMP.                285
Quench Reactor Approach              154
QUENCH ENERGY BLNCE      INLET    OUTLET
    ABSOLUTE TEMP          936       745
    SQRT T               30.59     27.29
    T SQRD              876096    555025
CP--H20 (Btu/Mole-F)      8.40      8.10
CP--CO2                  10.83      9.98
CP--O2                    7.53      7.27
Cp--N2                    7.09      6.90
Btu/Lb-FUEL in Gas         863       499
HEAT TO QUENCH          364.69 Btu/Lb
Lb H2O / Lb fuel          0.31       H2O BgHs Leak AH & DeNOx
MOLES ADDED / LB FUEL             0.0175    0.0049    0.0051
TOTAL MOLES FLUE GAS/LB FUEL      0.2590    0.2639    0.2415
QUENCHED GAS MOLE WEIGHT           27.53     27.57     28.24
FLUE GAS FLOW           TEMP-F      ACFM     DSCFM  MOISTURE
    SCRUBBER  OUTLET       285    118189     65059     21.1%
    BAGHOUSE OUTLET        284    120203     66626     20.7%
    STACK DISCHARGE        296    122153     66626     20.7%
    AIR HTR OUTLET         476    135545     63678     15.4%
STOICHIOMETRIC RATIO       1.6 ACID GAS        1.4 AMMONIA
EMISSIONS    LB/MBTU  LB/HR-in    EFFNCY Lb/Hr-out Lb/H-rgnt   gm/sec
  SO2          0.456    111.99    80.00%     22.40    174.16     2.82
  HCL          0.511    125.44    90.00%     12.54    171.20     1.58
  NOx          0.283     69.51    40.00%     41.71     36.01     5.26
  CO           0.126     30.94     0.00%     30.94        NA     3.90
  NMHC         0.005      1.23     0.00%      1.23        NA     0.15
  SLD PART     7.500   1842.26    99.85%      2.76        NA     0.35
  COND PAR     0.014      3.44    20.00%      2.75        NA     0.35
  TSP          7.514   1845.70    99.70%      5.51        NA     0.69
  DIOXIN     3.5e-09   8.6e-07    75.00%   2.1e-07        NA  2.7e-08
METHOD 5 IN gr/DSCF       3.38               0.010
FRONT HALF ONLY           3.37               0.005
      LIME-Lb/hr           345   ACTUAL SO2 RATIO       2.29 MOLAR
      AMMONIA-Lb/hr         36            SYSTEM WATER USAGE
                                       ClTwr Drif       1.13 GPM
FRACTION FLY ASH           10%         ClTwr Evap     204.92 GPM
RESIDUE MOISTURE CONTENT               ClTwr BloD      50.10 GPM
  BOTTOM ASH               35%         ClTwr MkUp     256.15 GPM
  FLY ASH & SCRUBBER       20%         Blr Lk&Los       4.65 GPM
RESIDUE WEIGHTS--Wet Basis             Blr BloDwn       6.19 GPM
  BOTTOM ASH-lb/hr       15023         Blr MakUp       10.85 GPM
  FLY ASH-lb/hr           1457         Dry Scrub       31.56 GPM
  REACTED LIME-lb/hr       482         Ash Cndtn       11.38 GPM
  HYDRATED LIME-lb/h       214                       -------
                       ------- TOTAL PROCESS WATER    309.93 GPM
 TOTAL RESIDUE-lb/hr     17177
```

TABLE 3 TYPICAL STACK EMISSION IMPACT CALCULATION

```
STACK HEIGHT          250 FEET               BOUYANCY FLUX       224.60 m4/s3
                       76 METERS

AMBIENT TEMP           60 F
                      520 R

STACK TEMP            296 F
                      756 R
                                             4 BOILERS ON LINE
STACK FLOW        488,612 ACFM         122,153 ACFM/BOILER

                                 STABILITY CLASS
                        A          B          C          D
----------------------------------------------------------------|
CRIT WIND SPEED         2          4          5          7 m/s
PLUME RISE            498        249        199        142 m
TOT PLUME HEIGH       575        325        276        219 m
SIGMA Z               406        230        195        155 m
DISTANCE TO MAX     0.989      1.984      3.517     12.849 km
PASCAL SIGMA Z        406        230        195        155 m
sigma Z closure      100%       100%       100%      100%
SIGMA Y               216        297        333        679 m
----------------------------------------------------------------|
Cmax--1hr        6.66e-07  4.27e-07  3.60e-07  1.59e-07 g/m3
Cmax--3hr        2.66e-07  3.71e-07  3.60e-07  1.59e-07 g/m3
Cmax--8hr        1.33e-07  1.92e-07  2.16e-07  1.59e-07 g/m3
Cmax--24hr       5.33e-08  5.55e-08  0.79e-07  1.16e-07 g/m3
-----------------------------------------------------------------------------|
                 EMISSION RATE                   maximum impact
   POLLUTANT      PER BOILER           1hr         3h       8hr     24hr
     SO2            2.82 g/s           7.51       4.19      2.44    1.31 ug/m3
     HCl            1.58 g/s           4.21       2.35      1.36    0.73 ug/m3
     NOx            5.26 g/s          14.01       7.81      4.54    2.44 ug/m3
     CO             3.90 g/s          10.39       5.79      3.37    1.81 ug/m3
     NMHC           0.14 g/s           0.37       0.21      0.12    0.06 ug/m3
     TSP            0.69 g/s           1.84       1.03      0.60    0.32 ug/m3
     DIOXIN      2.7e-08 g/s           0.07       0.04      0.02    0.01 ag/m3
-----------------------------------------------------------------------------|
```

annual average of 2000 TPD, through its four 600 TPD, rated boilers. The boilers are equipped with advanced air pollution control equipment (Specific non-catalytic reduction NO_x control and dry scrubber/baghouse).

Revenues

Typical waste-to-energy facility revenues include income from fees charged to dispose of solid waste and from the sale of recovered products.

Tip fees are the monies charged to deliver waste at the facility. The tipping fee is the only variable within the control of the project sponsor. The range of acceptable values of the tipping fee, however, is constrained by a community's ability to pay and the price of competing disposal options.

Energy price is affected by siting constraints and the availability of long term commitments for steam or electricity purchases. Electrical sales usually promise to be the easiest method of utilizing the heat generated from incinerating MSW in a waste-to-energy facility

TABLE 4 TYPICAL CALCULATION OF STACK EMISSIONS OF TRACE ELEMENTS

```
                                                             Normalized Emission Rate     29.914 g/sec//lb/Mbtu
                                                             Normalized Annual Impact       0.08 ug/m3//g/sec
                                                            +Normalized Hourly Emis.        2.72 ug/m3//g/sec
                                                            *Normalized Daily Impact        0.47 ug/m3//g/sec
                                                            'Normalized 8 hr Impact         0.88 ug/m3//g/sec
                                                            #Normalized 3 hr Impact         1.52 ug/m3//g/sec
                                                            @Normalzd Quarterly Impact      0.33 ug/m3//g/sec
-----------------------------------------------------------------------------------------------------------|
   ELEMENT  |lb/Mbtu    Fract.  Fract.  |  g/sec   |  ug/m3   |  TLV       AAC    Saftey | Potency          |
            |                   Emitted Substnc |          |          | mg/m3     ug/m3   Factor |  Slope    Risk   |
------------|--------------------------|----------|----------|--------------------------|------------------|
Arsenic     |     7.51    0.31%  1.0e-05| 6.89e-06| 5.51e-07|   0.500      1.14 2072174|3.21e-03  1.8e-09|
            |                          |          | 3.27e-06|   0.500*     3.33 1019073|                  |
            |                          |          | 1.87e-05|   0.002+     0.01     534|                  |
Beryllium   |     7.51    0.31%  1.0e-05| 6.91e-06| 5.53e-07|   0.002      0.00    8264|1.04e-03  5.7e-10|
            |                          |          | 3.28e-06|   0.005*     0.03   10160|                  |
            |                          |          | 1.88e-05|   0.000+     0.00     133|                  |
Cadmium     |     7.51    0.31%  6.5e-04| 4.51e-04| 3.61e-05|   0.050      0.11    3166|1.42e-03  5.1e-08|
            |                          |          | 2.14e-04|   0.040*     0.27    1246|                  |
            |                          |          | 1.23e-03|   0.200+     1.00     816|                  |
Chromium    |     7.51    0.31%  2.8e-05| 1.93e-05| 1.55e-06|   0.500      1.14  738582|0.88e-02  1.4e-08|
(hexavalent)|                          |          | 0.92e-05|   0.025*     0.17   18161|                  |
            |                          |          | 5.26e-05|   0.050+     0.25    4757|                  |
Nickel      |     7.51    0.31%  6.4e-03| 4.39e-03| 3.51e-04|   1.000      2.28    6498|2.46e-04  0.9e-07|
            |                          |          | 2.09e-03|   0.015*     0.10      48|                  |
Zinc        |     7.51    0.31%  2.4e-03| 1.62e-03| 1.30e-04|   1.000      2.28   17576|                  |
            |                          |          | 7.71e-04|   2.500*    16.67   21609|                  |
            |                          |          | 4.42e-03|  15.000+    75.00   16981|                  |
Vanadium    |     7.51    0.31%  4.5e-05| 3.10e-05| 2.48e-06|   0.050      0.11   46059|                  |
            |                          |          | 1.47e-05|   1.000*     6.67  453022|                  |
            |                          |          | 0.84e-04|   0.050+     0.25    2967|                  |
Copper      |     7.51    0.31%  2.4e-04| 1.68e-04| 1.34e-05|   0.200      0.46   33995|                  |
            |                          |          | 0.80e-04|   1.000*     6.67   83593|                  |
Manganese   |     7.51    0.31%  1.5e-03| 1.05e-03| 0.84e-04|   5.000     11.42  135542|                  |
Molybdemum  |     7.51    0.31%  0.7e-04| 5.17e-05| 4.14e-06|   5.000     11.42 2757373|                  |
Selenium    |     7.51    0.31%  1.1e-05| 7.59e-06| 6.07e-07|   0.200      0.46  752011|0.88e-02  5.3e-09|
            |                          |          | 3.61e-06|   0.200*     1.33  369831|                  |
Aluminum    |     7.51    0.31%  4.6e-02| 3.20e-02| 1.52e-02|   2.500*    16.67    1096|                  |
Antimony    |     7.51    0.31%  0.7e-04| 4.97e-05| 3.98e-06|   0.500      1.14  287027|                  |
            |                          |          | 2.36e-05|   0.500*     3.33  141157|                  |
Barium      |     7.51    0.31%  5.6e-04| 3.89e-04| 3.11e-05|   0.500      1.14   36703|                  |
            |                          |          | 1.85e-04|   0.500*     3.33   18050|                  |
Bromine     |     7.51    0.31%  1.2e-04| 0.83e-04| 6.62e-06|   0.327      0.75  112708|                  |
            |                          |          | 3.93e-05|   0.327*     2.18   55428|                  |
Calcium     |     7.51    0.31%  1.2e-02| 0.83e-02| 6.62e-04|  10.000     22.83   34467|                  |
Europium    |     7.51    0.31%  2.0e-06| 1.38e-06| 1.10e-07|                          |                  |
Gallium     |     7.51    0.31%  1.5e-04| 1.03e-04| 0.83e-05|                          |                  |
Magnesium   |     7.51    0.31%  1.9e-04| 1.31e-04| 1.05e-05|   2.500      5.71  544218|                  |
Phosphorus  |     7.51    0.31%  1.4e-03| 9.66e-04| 0.77e-04|   0.100      0.23    2954|                  |
            |                          |          | 4.59e-04|   0.100*     0.67    1453|                  |
Potassium   |     7.51    0.31%  1.2e-03| 8.28e-04| 0.66e-04|   2.500      5.71   86168|                  |
Silicon     |     7.51    0.31%  0.9e-01| 6.21e-02| 4.97e-03|  10.000     22.83    4596|                  |
Sodium      |     7.51    0.31%  3.0e-03| 2.07e-03| 1.66e-04|   5.000     11.42   68934|                  |
Strontium   |     7.51    0.31%  8.0e-04| 5.52e-04| 4.42e-05|                          |                  |
Mercury     | 0.87e-05 100.00%  1.0e+00| 2.59e-04| 2.07e-05|   0.050      0.11    5510|                  |
            |                          |          | 1.23e-04|   0.050*     0.33    2710|                  |
            |                          |          | 7.04e-04|   0.100+     0.50     710|                  |
 Acid Gas   |    0.511   10.34%  1.0e+00| 1.58e+00| 1.26e-01|   5.000    333.00 2634.49|                  |
-----------------------------------------------------------------------------------------------------------|
Criteria Pollutants                    |          |          |        S     AQS         |                  |
 Sulfur Diox|    0.456   20.67%  1.0e+00| 2.82e+00| 2.26e-01|               80      355|                  |
            |                          |          | 1.34e+00|        *     365      272|                  |
            |                          |          | 4.29e+00|        #    1300      303|                  |
 Nit. Diox  |    0.283   62.13%  1.0e+00| 5.26e+00| 4.21e-01|              100      238|                  |
 Carbon Mono|    0.126  103.47%  1.0e+00| 3.90e+00| 2.81e-01|        '      72      256|                  |
            |                          |          | 3.12e-01|              259      830|                  |
 VOC        |    0.005  100.00%  1.0e+00| 1.50e-01| 1.20e-02|                          |                  |
 Particulate|     7.51    0.31%  1.0e+00| 6.90e-01| 5.52e-02|              491     8895|                  |
            |                          |          | 1.88e+00|        *      36       19|                  |
 Lead       |     7.51    0.31%  6.7e-04| 4.65e-04| 1.54e-04|        @     1.5     9769|                  |
-----------------------------------------------------------------------------------------------------------|
Trace Organics                         |          |          |                          |                  |
 B(a)P      | 5.72e-08 100.00%  1.0e+00| 1.71e-06| 1.37e-07|                          |2.46e-03  3.4e-10|
 PCB        | 6.71e-07 100.00%  1.0e+00| 2.01e-05| 1.61e-06|                          |9.29e-04  1.5e-09|
 2378TCDDeq | 6.54e-09  25.00%   100.0%| 4.89e-08| 3.91e-09|          1.2e-05     3069|2.09e+00  0.8e-08|
   internat |                          |          |          |                            (12/87)   -------|
            |                          |          |          |Combinded risk due to Metals         1.6e-07|
            |                          |          |          |Combined risk due to Organics        1.0e-08|
            |                          |          |          |Total Plant Risk                     1.7e-07|
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```

TABLE 5 TYPICAL PROFORMA ACCRUAL STATEMENT

YEAR	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
AVERAGE ¢/kW	3.96	4.21	4.47	4.83	4.88	5.17	5.54	5.61	5.95	6.32
LONG/SHORT TG OUTAGE	0	0	0	1	0	0	0	1	0	0
NET GENERATION	4,624	4,624	4,624	4,466	4,624	4,624	4,624	4,466	4,624	4,624
TPY MSW	750,699	750,699	750,699	750,699	750,699	750,699	750,699	750,699	750,699	750,699
TIP FEE $/T	46.09	48.40	50.82	53.36	56.02	58.83	61.77	64.86	68.10	71.50
BYPASS LF--TIP	3.23	3.40	3.56	3.74	3.93	4.13	4.33	4.55	4.78	5.02
--DIST	1	1	1	1	1	1	1	1	1	1
RESIDUE LF--TIP	3.23	3.40	3.56	3.74	3.93	4.13	4.33	4.55	4.78	5.02
--DIST	1	1	1	1	1	1	1	1	1	1
REVENUES IN $,000										
ENERGY	18298	19462	20681	21561	22572	23914	25611	25065	27521	29244
CAPACITY	0	0	0	0	0	0	0	0	0	0
TIPPING	34601	36331	38147	40055	42058	44160	46369	48687	51121	53677
TOTAL REVENUES	52899	55793	58828	61616	64629	68074	71980	73752	78642	82921
EXPENSES IN $,000										
OPERATING LABOR	2932	3078	3232	3394	3563	3742	3929	4125	4331	4548
MAINTAINCE LABOR	538	565	593	623	654	687	721	757	795	835
MAINT. PART & SUPLY	1399	1846	3092	3519	4023	4224	4436	4657	4890	5135
LIME	525	552	579	608	638	670	704	739	776	815
AMMONIA	204	214	225	236	248	260	273	287	301	316
BOILER CHEMICALS	157	164	173	181	190	200	210	220	231	243
INSURANCE	853	896	940	987	1037	1089	1143	1200	1260	1323
RAW WASTE HAULING	0	0	0	0	0	0	0	0	0	0
RAW WASTE TIP	0	0	0	0	0	0	0	0	0	0
OUTSIDE SERVICES	348	366	384	778	424	445	467	945	515	541
BID BUDGET	6956	7681	9219	10326	10778	11317	11882	12931	13100	13755
MAINT. CONTRACTS	2698	3049	3298	3463	3636	3817	4008	4209	4419	4640
RESIDUE HAULING	60	63	66	70	73	77	81	85	89	93
RESIDUE TIP	706	741	778	817	858	901	946	993	1043	1095
WATER	787	827	868	911	957	1005	1055	1108	1163	1221
SEWER	94	99	104	109	114	120	126	132	139	146
GAS	38	40	42	44	46	48	51	53	56	59
PURCHASED POWER	0	0	0	0	0	0	0	0	0	0
MOBILE EQUIPMENT	391	317	432	449	476	385	525	546	578	468
SUBTOTAL	4775	5135	5587	5862	6160	6353	6791	7126	7487	7723
FIXED FEE	970	1019	1069	1123	1179	0	0	0	0	0
SUBSTATION-O&M	134	141	148	155	163	171	179	188	198	208
STANDBY CAPACITY	54	57	60	63	66	69	73	76	80	84
MAINTAINCE RESERVF	782	854	987	1079	1129	1178	1245	1337	1373	1432
CAPITAL RESERVE	391	427	494	540	565	589	622	669	686	716
TOTAL ANNUAL O&M	14062	15313	17563	19148	20039	19677	20793	22328	22924	23918
GROSS REVENUE	38837	40480	41265	42468	44590	48397	51187	51425	55718	59003
INTEREST EARNINGS	2905	2905	2905	2905	2905	2905	2905	2905	2905	2905
DEBT SERVICE	-39000	-39000	-39000	-39000	-39000	-39000	-39000	-39000	-39000	-39000
NET REVENUE	2742	4385	5170	6373	8495	12302	15092	15330	19623	22909
DEBT SERV COVERAGE	1.10	1.15	1.17	1.20	1.26	1.36	1.43	1.44	1.56	1.64

because of the Public Utilities Regulatory Power Act of 1978. Even with an attractive steam price, supply reliability or load following requirements may be too onerous; financing may be impaired due to usual steam buyer escape clauses.

Recycled material sales prices are affected by recovered material quality and the availability of long term materials sales contracts.

Expenses

Typical expense items include both direct and indirect costs of operation. When cash flow is considered from the private perspective, allowances for taxes and fees must be added.

Standby capacity and purchase power expenses include an allowance for back-up energy supplies when the in-plant turbines are off-line for repairs or maintenance. The amount of energy purchased increases during years when the turbine is brought off-line for major maintenance.

Labor is required for normal operation and maintenance of a facility. A plant's labor costs are generally unique and are determined by the facility's staffing plan, the prevailing wage rates, the fringe benefit packages, and local labor productivity.

Maintenance parts and supply costs cannot be reliably predicted for the refuse specific components of a facility. However, the balance of the plant can be reliably estimated using industrial power plant guidelines. Published information for waste-to-energy facilities is sparse and is frequently inconsistent owing to different cost accounting methods and being inherently site and facility specific. Estimates are proportional to tonnage processed.

Consumable expenses include auxiliary fuel, reagents for the air pollution control and water treatment systems, water, and internally used electricity. The quantity of consumables used is normally related to the amount of waste burned and its composition.

Electricity purchase costs can be related to the major energy consumption centers of the facility (boilers, fuel preparation, scrubbers, powerblock, etc.). This estimate is based on the equipment installed, what is operating, individual motor load factors, etc.

Water purchase cost is determined by the type and size of the facility. Water is used in the acid gas scrubber, cooling tower, boiler feed make-up water, and sanitary and housekeeping uses. Sewer cost is estimated accounting for winter losses in flue gas acid and ash streams.

Reagent is consumed in acid gas scrubbers and the amount used is determined by the amount of waste burned, the sulfur and chlorine content of the waste, and the design parameters of the scrubbers, which includes the ratio of reagent to each unit of acid gas removed.

Boiler chemicals such as sulfuric acid, sodium hydroxide, sodium hypochlorite, hydrazine, etc. are usually consumed in small quantities. Their consumption is generally in direct proportion to boiler water consumption and can be estimated from boiler and water balances. For initial screening purposes, these costs are small enough to be taken as negligible.

Bypass and residue disposal expenses are determined by the amount of waste delivered to the facility that is not processed ("bypassed" to the landfill) and the cost of disposing the incinerator ash and air pollution control equipment residue. Disposal costs include both transportation and tipping fee. Because of the regulatory uncertainty concerning the proper management of ash, it is prudent to be able to separately estimate the cost of disposing ash, including air pollution control residues and bypassed waste. The tipping fees are location specific.

Substation leasing expense (if applicable) is determined by the energy contract with the purchasing utility and the scope of the supply negotiated with the local utility.

Insurance expense is determined by market quotes for the usual natural hazards, the business interruption, and the boiler and machinery insurance protection.

Maintenance and capital reserve expenses are needed to provide extra money to repair and upgrade the facility due to emergencies. Setting aside 1% of the energy revenues and 20% of the expected maintenance costs has been recommended by several underwriters.

Debt Service requirements are determined by the project's hard and soft costs, the reserve requirements, and bond market conditions. Table 6 shows an example of a bond build-up for a waste-to-energy facility. This example is based on an average interest rate of 9%, a 33 month construction period with a funded reserve of 3 months construction time for delays, and the indicated reserve, discount, and issuance costs. A uniform construction fund drawdown, land and owner's costs, reserves, and insurance during construction are based upon recent experience with financings of this size. Bond interest and monthly re-investment rates are highly speculative and any guess by other than a bond analyst would be inappropriate.

Proforma Balance Sheet Summary

When the preceding estimated expense elements are totaled, an annual operation and maintenance expense

TABLE 6 TYPICAL BOND BUILD-UP

Mo.Dev Per	24
Mo const per	32
Mo demonstration	1
Mo Reserve	3

Time to Com. Ops	57 MONTHS
Bonded Interest	60 MONTHS

Period	Mon Mult	Rate		
0-6	0.585%	7.25%	9.00%	Long Bond Rate
7-12	0.585%	7.25%	5.25%	Fund Int Period
13-18	0.585%	7.25%	1.052	1+Bnd Rate
19-24	0.585%	7.25%	9.00%	Const Loan
15-30	0.585%	7.25%	0.720%	Mon Spread
31-36	0.585%	7.25%	30	Yr Term
Term	0.585%	7.25%	0	Refin @ Const Start

	VALUE	PRESENT VALUE OR PV MULTIPLIER	ISSUE
	------------	----------	----------------
FUNDED INTEREST	0.2625 * BOND	0.2154	$105,176
DEBT SERVICE RESERVE	0.1000 * BOND	0.0705	$40,067
DISCOUNT & ISSUANCE	0.0622 * BOND	0.0622	$24,922
NET OF CONST. LOAN INTEREST EARNINGS			(21,823)
FINANCED COST			
WTE Facility	$199,481 }		$252,329
Landfill Facility	$9,000 }	$221,167	
Const. Reserves	$20,848	$21,359	
Const Services	$10,424	$6,256	
Project Developmnt	$7,000	$6,320	
Renew,Replace,Imp.	$0	$0	
Site Acquisition	$1,575	$1,361	
Insurance	$4,000	$4,143	
	-------	-------	
SUB-TOTAL	$252,329	$261,207	

			$400,670
Construction Loan		ISSUE SIZE	$400,670
Principal	$233,329	ANNUAL DEBT SERVICE	$39,000
Interest	$117,549	ANNUAL INTEREST EARNINGS	$2,905

estimate will be obtained. By adding the interest earned on reserve accounts and by deducting the debt service payments from gross revenue, net facility revenue is determined.

Net revenues must be greater than zero in order to avoid increasing tipping fees. Otherwise, a community faces subsidizing the facility from general revenues and a private developer faces bankruptcy. For sound projects backed by substantial sponsors, an acceptable ratio of net revenue to net debt service ("coverage") is usually more than 1.2. During the early development stages of a project, when estimates are softest, a ratio of 1.5 or higher is prudent. Final coverage requirements must be provided by a financial advisor or underwriter since bond marketing requirements, govern project structure and security arrangements determine the requirement.

Summary Values

It is generally useful to summarize the available information by using key summary values. The MPCD computer model enables the rapid determination of the following typical:

(a) The maximum break-even tipping fee for the facility life expressed in current dollars.

(b) For a fixed tipping fee or formula, the number of years an outside subsidy will be required.

(c) The maximum fraction of available air pollution increment consumed.

(d) The fraction of waste expected to be bypassed.

(e) The tonnage or volumetric reduction achieved.

(f) The size of the required financing.

By focusing on a few key indicators, the comparative ranking of alternatives can be established and the impact of changes on the project definition becomes apparent to all interested parties. This is particularly important when project feasibility can be constrained by public concerns, low debt limits, state bond caps and very tight municipal budgets.

CONCLUSION

The PCD concept can be extended from its very simple beginnings and generalized assumptions with the inclusion of a constantly updated computer model of its contents. The strength of the MPCD is its ability to function from very early project stages and grow through plant operations. This centralized source of data and integrated computing provides the opportunity to quickly, and with full awareness of cascading impacts, evaluate alternatives and make decisions when events or options come before the project. In the past, similar situations would have required either lengthy and tedious calculations or management decision by intuition. These decisions can be made with much more confidence with an MPCD available.

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