EBS - Core Billing & Rating Engine

Functional Specification Document

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1. Introduction & Scope

1.1 Purpose

This document defines the complete functional requirements for the Energy Billing System's Core Billing and Rating Engine. This engine represents the heart of the EBS platform, responsible for transforming raw meter usage data into accurate, compliant, and customer-friendly billing invoices.

1.2 Scope

This specification covers:

- Meter data ingestion from smart grid infrastructure
- Validation and normalization of usage data

- Application of rate plans and tariff structures
- Calculation of billing amounts including taxes, fees, and adjustments
- Generation of invoice line items and supporting documentation
- Handling of partial billing cycles, back-billing, and corrections
- Integration touchpoints with upstream (meter systems) and downstream (invoice delivery) services

This specification does NOT cover:

- Physical meter reading processes (covered in Smart Grid Integration spec)
- Payment processing (covered in Payment Gateway Integration spec)
- Customer self-service portal (covered in Customer Portal Requirements)
- Reporting and analytics (covered in Business Intelligence spec)

1.3 Key Stakeholders

- **Finance Team:** Revenue accuracy, audit compliance, tax calculation
- **Customer Support:** Bill explanation, dispute resolution
- **Regulatory Compliance:** Tariff approval processes, audit requirements
- **IT Operations:** System reliability, performance, maintainability

1.4 Business Context

The billing engine must process approximately 2.3 million residential and 180,000 commercial customer accounts monthly. The system operates on a monthly billing cycle with staggered billing dates throughout the month (approximately 80,000 customers per day). Peak processing occurs between the 15th and 25th of each month.

Critical business constraints:

- **Accuracy Target:** Less than 0.1% billing error rate (target: 2,300 or fewer errors per billing cycle)
- **Processing Window:** Complete daily billing runs within 8-hour processing window
- **Regulatory Compliance:** All calculations must maintain complete audit trail per PUC requirements
- **Financial Impact:** System processes approximately $145M in monthly billing

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2. Billing Process Overview

2.1 High-Level Process Flow

The billing process follows a six-stage pipeline architecture:

Stage 1: Meter Data Acquisition
Smart meters transmit usage data every 15 minutes to the grid management system. At billing cycle close, the system aggregates interval data and transmits complete usage records to the EBS Meter Ingestion Service.

Stage 2: Data Validation & Normalization
The Ingestion Service validates data completeness, checks for anomalies, and normalizes data into the EBS standard usage record format. Invalid or incomplete records are flagged for manual review.

Stage 3: Rate Plan Determination
The Rating Service identifies the appropriate rate plan(s) for each customer account based on customer type, service class, enrollment date, and any special programs (e.g., low-income assistance, renewable energy programs).

Stage 4: Usage Calculation
The system calculates billable consumption by applying rate plan rules, including tier thresholds, time-of-use periods, demand charges, and any applicable riders or surcharges.

Stage 5: Amount Calculation
The Billing Calculation Engine applies unit rates to calculated usage, adds fixed charges, calculates applicable taxes, and determines the total amount due.

Stage 6: Invoice Generation
The Invoice Generation Service creates invoice records with detailed line items, generates PDF documents, and queues invoices for delivery via email, postal mail, or customer portal.

2.2 System Architecture Context

[Smart Meter Network]

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[Grid Management System API]

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[Meter Ingestion Service] → [Usage Data Store (PostgreSQL)]

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[Rating Service] → [Rate Plan Repository]

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[Billing Calculation Engine] → [Tax Calculation Service]

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[Invoice Generation Service] → [Invoice Repository]

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[Delivery Services: Email/Print/Portal]

2.3 Data Flow & Timing

Daily Processing Schedule:

- 00:00-02:00 IDT: Meter data acquisition from smart grid API
- 02:00-04:00 IDT: Data validation and normalization
- 04:00-09:00 IDT: Rating and billing calculation for daily batch
- 09:00-10:00 IDT: Invoice generation and quality assurance checks
- 10:00-11:00 IDT: Invoice delivery processing
- 11:00+ IDT: Exception handling and manual review queue processing

Billing Cycle Calendar:

Customers are distributed across 30 billing cycle groups (approximately 80,000 customers each). Each cycle group has a fixed cycle close date (1st through 30th of month). Invoices are generated within 48 hours of cycle close and have payment due dates 21 days after invoice date.

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3. Meter Data Processing

3.1 Input Data Sources

Primary Source: Smart Grid Gateway API

The smart grid infrastructure provides usage data through a RESTful API. The system supports two data retrieval modes:

Push Mode (Preferred): Smart grid system pushes completed billing cycle data to EBS webhook endpoint when cycle closes. Payload format: XML or JSON (configurable).

Pull Mode (Backup): EBS polls smart grid API every 2 hours checking for completed cycles. Used as fallback if push notifications fail.

3.2 Input Data Format

XML Schema Example:

```
<MeterReadingBatch>
  <Header>
    <BatchID>MR-2025-10-03-0001</BatchID>
    <TransmissionDateTime>2025-10-03T02:15:30Z</TransmissionDateTime>
    <RecordCount>82,447</RecordCount>
    <CycleCloseDate>2025-10-02</CycleCloseDate>
  </Header>
  <Readings>
    <Reading>
      <MeterID>MTR-894512-A</MeterID>
      <CustomerAccountID>CUST-2847563</CustomerAccountID>
      <ServiceAddress>
        <StreetAddress>1247 Oak Street</StreetAddress>
        <City>Petah Tikva</City>
        <PostalCode>4912001</PostalCode>
      </ServiceAddress>
      <ReadingPeriod>
        <StartDate>2025-09-03</StartDate>
        <EndDate>2025-10-02</EndDate>
        <DaysCovered>30</DaysCovered>
      </ReadingPeriod>
```

```
      <Usage>
        <TotalKWh>847.3</TotalKWh>
        <PeakKWh>412.5</PeakKWh>
        <OffPeakKWh>434.8</OffPeakKWh>
        <MaxDemandKW>4.2</MaxDemandKW>
        <MaxDemandDateTime>2025-09-15T14:30:00Z</MaxDemandDateTime>
      </Usage>
      <PreviousReading>
        <Date>2025-09-03</Date>
        <Value>145823</Value>
      </PreviousReading>
      <CurrentReading>
        <Date>2025-10-02</Date>
        <Value>146670.3</Value>
      </CurrentReading>
      <ReadingQuality>VERIFIED</ReadingQuality>
      <EstimatedFlag>false</EstimatedFlag>
    </Reading>
    <!-- Additional readings... -->
  </Readings>
</MeterReadingBatch>
```

JSON Schema Example:

```
{
  "batchId": "MR-2025-10-03-0001",
  "transmissionDateTime": "2025-10-03T02:15:30Z",
  "recordCount": 82447,
  "cycleCloseDate": "2025-10-02",
  "readings": [
    {
      "meterId": "MTR-894512-A",
      "customerAccountId": "CUST-2847563",
      "serviceAddress": {
        "streetAddress": "1247 Oak Street",
        "city": "Petah Tikva",
        "postalCode": "4912001"
      },
      "readingPeriod": {
        "startDate": "2025-09-03",
        "endDate": "2025-10-02",
        "daysCovered": 30
      },
      "usage": {
        "totalKWh": 847.3,
        "peakKWh": 412.5,
```

```
      "offPeakKWh": 434.8,
      "maxDemandKW": 4.2,
      "maxDemandDateTime": "2025-09-15T14:30:00Z"
    },
    "previousReading": {
      "date": "2025-09-03",
      "value": 145823
    },
    "currentReading": {
      "date": "2025-10-02",
      "value": 146670.3
    },
    "readingQuality": "VERIFIED",
    "estimatedFlag": false
  }
 ]
}
```


3.3 Data Validation Rules

The Meter Ingestion Service applies comprehensive validation before accepting meter data:

Validation Rule V-001: Meter ID Validation

- **Rule:** Meter ID must exist in EBS Meter Registry and be in ACTIVE status
- **Action on Failure:** Reject reading, log error, notify Smart Grid team
- **Error Code:** METER_NOT_FOUND or METER_INACTIVE

Validation Rule V-002: Customer Account Linkage

- **Rule:** Customer Account ID must exist and be linked to the specified Meter ID
- **Action on Failure:** Reject reading, flag for manual resolution
- **Error Code:** ACCOUNT_METER_MISMATCH

Validation Rule V-003: Usage Value Range

- **Rule:** Total kWh must be > 0 and < 50,000 for residential (adjusted for commercial)
- **Rationale:** Negative usage indicates data error; extremely high usage suggests meter malfunction
- **Action on Failure:** Flag for manual review, do not auto-bill
- **Error Code:** USAGE_OUT_OF_RANGE

Validation Rule V-004: Usage Reasonableness Check

- **Rule:** Current billing period usage must be within 200% of historical average (calculated over previous 12 months, excluding outliers)
- **Action on Failure:** Flag for manual review but allow processing
- **Warning Code:** USAGE_ANOMALY_DETECTED

Validation Rule V-005: Meter Reading Progression

- **Rule:** Current reading value must be >= previous reading value (accounting for meter rollover at 999,999)
- **Action on Failure:** Reject reading, flag for meter inspection
- **Error Code:** READING_REGRESSION

Validation Rule V-006: Billing Cycle Duration

- **Rule:** Days covered must be between 25-35 days for monthly billing cycles
- **Action on Failure:** Flag for review but allow processing; adjust calculation methodology
- **Warning Code:** PARTIAL_CYCLE

Validation Rule V-007: Estimated Reading Policy

- **Rule:** No more than 2 consecutive estimated readings allowed per account
- **Action on Failure:** Escalate for actual meter reading; block further estimates
- **Error Code:** EXCESSIVE_ESTIMATES

Validation Rule V-008: Time-of-Use Data Completeness

- **Rule:** For TOU rate plans, peak + off-peak kWh must equal total kWh (within 0.1% tolerance)

- **Action on Failure:** Reject reading, request corrected data from Smart Grid
- **Error Code:** TOU_DATA_MISMATCH

Validation Rule V-009: Data Transmission Timeliness

- **Rule:** Meter data must be received within 72 hours of cycle close date
- **Action on Failure:** Flag account for possible delayed billing
- **Warning Code:** LATE_METER_DATA

Validation Rule V-010: Demand Reading Consistency

- **Rule:** Max demand kW must be > 0 for commercial accounts with demand charges
- **Action on Failure:** Use calculated demand from interval data as fallback
- **Warning Code:** DEMAND_READING_MISSING

3.4 Data Normalization Process

After validation, the system normalizes meter data into the standard EBS Usage Record format:

EBS Usage Record Schema:

```
{

  "usageRecordId": "UUID",

  "customerAccountId": "STRING",

  "meterId": "STRING",

  "billingCycleId": "STRING",

  "periodStartDate": "DATE",

  "periodEndDate": "DATE",

  "numberOfDays": "INTEGER",

  "totalConsumptionKWh": "DECIMAL(10,2)",

  "peakConsumptionKWh": "DECIMAL(10,2)",

  "offPeakConsumptionKWh": "DECIMAL(10,2)",

  "maxDemandKW": "DECIMAL(8,3)",
```

```
  "maxDemandDateTime": "DATETIME",
  "previousMeterReading": "DECIMAL(10,2)",
  "currentMeterReading": "DECIMAL(10,2)",
  "readingQualityCode": "ENUM(VERIFIED, ESTIMATED, CUSTOMER_PROVIDED)",
  "isPartialCycle": "BOOLEAN",
  "partialCycleReason": "STRING",
  "dataSource": "STRING",
  "receivedDateTime": "DATETIME",
  "processedDateTime": "DATETIME",
  "validationStatus": "ENUM(VALID, WARNING, ERROR)",
  "validationMessages": "ARRAY[STRING]"
}
```

Normalization Transformations:

1. **Date Standardization:** Convert all dates to ISO 8601 format, UTC timezone
2. **Decimal Precision:** Round all usage values to 2 decimal places
3. **Unit Conversion:** Ensure all consumption in kWh, demand in kW
4. **Null Handling:** Replace null values with appropriate defaults (0 for optional numeric fields, empty string for optional text)
5. **Account Linking:** Enrich record with customer demographic data (rate class, service territory, program enrollments)

3.5 Exception Handling for Meter Data

Estimated Readings:

When actual meter readings are unavailable, the system generates estimated readings based on historical consumption patterns:

- Calculate average daily consumption from previous 12 months (excluding outliers)
- Apply seasonal adjustment factor (winter months typically 15% higher for heating)
- Multiply by billing cycle days to derive estimated consumption
- Flag invoice prominently as "ESTIMATED BILL"

- Ensure true-up on next actual reading with adjustment line item

Missing Meter Data:

If meter data is not received within 72 hours of cycle close:

- Send automated alert to Smart Grid operations team
- Hold billing for up to 7 days pending data receipt
- After 7 days, generate estimated bill to maintain billing schedule
- Track all delayed accounts for priority processing when data arrives

Meter Replacement Scenarios:

When a meter is replaced mid-cycle:

- Calculate usage from old meter: (final reading - cycle start reading)
- Calculate usage from new meter: (cycle end reading - installation reading)
- Sum both components for total cycle usage
- Document meter change in invoice notes
- Apply standard validation rules to combined usage

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4. Rate & Tariff Management

4.1 Rate Plan Overview

The EBS supports multiple rate plan categories designed to serve different customer segments and policy objectives:

Residential Rate Plans:

- R1: Standard Residential Tiered Rate
- R2: Time-of-Use Residential Rate
- R3: Low-Income Assistance Rate (CARE program)
- R4: Electric Vehicle Owner Rate
- R5: Solar Net Metering Rate

Commercial Rate Plans:

- C1: Small Commercial Flat Rate
- C2: Medium Commercial Demand Rate
- C3: Large Commercial Time-of-Use with Demand
- C4: Industrial High Voltage Rate

Special Program Rates:

- SP1: Medical Baseline Allowance
- SP2: Renewable Energy Premium Rate
- SP3: Peak Time Rebate Program

4.2 Rate Plan R1: Standard Residential Tiered Rate (Detailed Specification)

Eligibility: All residential customers not enrolled in other specific programs

Rate Structure:

The R1 rate plan uses a two-tier increasing block rate structure designed to encourage conservation. Higher consumption is charged at a higher rate to promote energy efficiency.

Tier 1 (Baseline Allowance): 0 - 500 kWh

- Summer Rate (June 1 - September 30): $0.1247 per kWh
- Winter Rate (October 1 - May 31): $0.1198 per kWh

Tier 2 (Above Baseline): > 500 kWh

- Summer Rate: $0.1584 per kWh
- Winter Rate: $0.1498 per kWh

Fixed Monthly Charges:

- Service Charge: $15.00 (covers meter reading, billing, and customer service)
- Infrastructure Maintenance Fee: $3.50 (supports grid modernization)

Seasonal Adjustment Logic:

The season is determined by the billing cycle end date:

- If cycle end date falls between June 1 and September 30: Apply summer rates
- If cycle end date falls between October 1 and May 31: Apply winter rates
- For partial cycles spanning season boundaries: Prorate based on days in each season

Rate Application Algorithm:

For each billing cycle:

1. Determine applicable season based on cycle end date
2. Retrieve seasonal tier rates for R1
3. Calculate Tier 1 consumption: MIN(total_kwh, 500)
4. Calculate Tier 2 consumption: MAX(0, total_kwh - 500)
5. Calculate Tier 1 charges: tier1_kwh × tier1_rate
6. Calculate Tier 2 charges: tier2_kwh × tier2_rate
7. Sum energy charges: tier1_charges + tier2_charges
8. Add fixed service charge: $15.00
9. Add infrastructure fee: $3.50
10. Calculate subtotal before taxes
11. Apply tax calculation (see section 4.6)

Example Calculation for R1 (750 kWh, Winter Season):

Total Consumption: 750 kWh

Season: Winter (cycle end date: October 15, 2025)

Tier 1 Calculation:

Consumption in Tier 1: 500 kWh (baseline allowance)

Rate: $0.1198/kWh

Tier 1 Charges: 500 × $0.1198 = $59.90

Tier 2 Calculation:

Consumption in Tier 2: 750 - 500 = 250 kWh

Rate: $0.1498/kWh

Tier 2 Charges: 250 × $0.1498 = $37.45

Energy Subtotal: $59.90 + $37.45 = $97.35

Fixed Charges:

Service Charge: $15.00

Infrastructure Fee: $3.50

Fixed Charges Total: $18.50

Subtotal Before Tax: $97.35 + $18.50 = $115.85

Taxes (see section 4.6):

State Energy Tax (3.5%): $115.85 × 0.035 = $4.05

Local Utility Tax (1.8%): $115.85 × 0.018 = $2.09

Total Taxes: $6.14

TOTAL AMOUNT DUE: $121.99

4.3 Rate Plan R2: Time-of-Use Residential Rate

Eligibility: Residential customers who opt-in; requires smart meter with interval data capability

Purpose: Encourages energy consumption during off-peak hours when grid demand is lower, reducing strain on infrastructure and promoting grid efficiency.

Rate Structure:

Peak Hours (2:00 PM - 8:00 PM, Monday-Friday, excluding holidays):

- Summer: $0.2145 per kWh
- Winter: $0.1987 per kWh

Off-Peak Hours (All other times):

- Summer: $0.0895 per kWh
- Winter: $0.0847 per kWh

Super Off-Peak (12:00 AM - 6:00 AM, All days):

- Summer: $0.0675 per kWh
- Winter: $0.0652 per kWh

Fixed Monthly Charges:

- Service Charge: $12.00 (reduced to incentivize TOU enrollment)
- Infrastructure Maintenance Fee: $3.50

Peak Hour Definitions:

The system uses a comprehensive calendar of peak/off-peak periods:

Recognized Holidays (Off-Peak All Day):

- New Year's Day
- Memorial Day
- Independence Day
- Labor Day
- Thanksgiving Day
- Christmas Day
- Any officially declared utility emergency days

TOU Period Determination Algorithm:

For each 15-minute interval in billing cycle:

1. Check if date is recognized holiday → classify as OFF_PEAK
2. Check day of week:
   - If Saturday or Sunday → classify as OFF_PEAK
   - If Monday-Friday:
     a. If time between 00:00-06:00 → classify as SUPER_OFF_PEAK
     b. If time between 14:00-20:00 → classify as PEAK
     c. Otherwise → classify as OFF_PEAK
3. Accumulate kWh consumption into respective period buckets
4. At cycle end, sum all intervals by period type

Example Calculation for R2 (850 kWh, Summer Season):

Total Consumption: 850 kWh

Breakdown by Period:

- Peak (2PM-8PM weekdays): 245 kWh
- Off-Peak (other times): 425 kWh
- Super Off-Peak (12AM-6AM): 180 kWh

Peak Charges:

245 kWh × $0.2145/kWh = $52.55

Off-Peak Charges:

425 kWh × $0.0895/kWh = $38.04

Super Off-Peak Charges:

180 kWh × $0.0675/kWh = $12.15

Energy Subtotal: $52.55 + $38.04 + $12.15 = $102.74

Fixed Charges:

Service Charge: $12.00

Infrastructure Fee: $3.50

Fixed Charges Total: $15.50

Subtotal Before Tax: $102.74 + $15.50 = $118.24

Taxes (5.3% combined): $6.27

TOTAL AMOUNT DUE: $124.51

4.4 Rate Plan C2: Medium Commercial Demand Rate

Eligibility: Commercial accounts with peak demand between 20 kW and 100 kW

Rate Structure:

Energy Charges (Flat Rate):

- $0.1095 per kWh (all consumption)

Demand Charges:

- $12.50 per kW of maximum demand recorded during billing period
- Minimum billable demand: 10 kW
- Demand is measured as the highest 15-minute average kW during the cycle

Fixed Monthly Charges:

- Service Charge: $35.00
- Infrastructure Maintenance Fee: $8.00

Demand Calculation Methodology:

The system analyzes all 15-minute interval data to determine the peak demand:

For each 15-minute interval in billing cycle:

1. Calculate average kW for interval: kWh_interval / 0.25 hours
2. Track maximum kW across all intervals
3. Round maximum kW to nearest 0.1 kW
4. Apply minimum demand threshold (10 kW)
5. Billable demand = MAX(10, recorded_maximum_kW)

Example Calculation for C2:

Total Consumption: 3,250 kWh

Maximum Recorded Demand: 47.3 kW (occurred on Sept 18 at 14:15)

Energy Charges:

3,250 kWh × $0.1095/kWh = $355.88

Demand Charges:

47.3 kW × $12.50/kW = $591.25

Fixed Charges:

Service Charge: $35.00

Infrastructure Fee: $8.00

Fixed Charges Total: $43.00

Subtotal Before Tax: $355.88 + $591.25 + $43.00 = $990.13

Commercial Taxes (6.2% combined): $61.39

TOTAL AMOUNT DUE: $1,051.52

4.5 Rate Plan Configuration System

Rate Definition Storage:

All rate plans are stored as JSON configuration documents in the Rate Plan Repository (PostgreSQL JSONB column). This allows business users to modify rate structures without code deployment.

Sample Rate Configuration JSON:


```
{
  "ratePlanCode": "R1",
  "ratePlanName": "Standard Residential Tiered Rate",
  "effectiveDate": "2025-01-01",
  "expirationDate": null,
  "customerClass": "RESIDENTIAL",
  "eligibilityCriteria": {
    "customerTypes": ["RESIDENTIAL"],
    "excludedPrograms": ["CARE", "SOLAR_NEM"]
  },
  "rateStructure": {
```

```
"type": "TIERED_ENERGY",
"tiers": [
  {
    "tierNumber": 1,
    "thresholdKWh": 500,
    "rates": {
      "summer": 0.1247,
      "winter": 0.1198
    }
  },
  {
    "tierNumber": 2,
    "thresholdKWh": 999999,
    "rates": {
      "summer": 0.1584,
      "winter": 0.1498
    }
  }
],
"seasonDefinitions": {
  "summer": {
    "startMonth": 6,
```

```
      "startDay": 1,
      "endMonth": 9,
      "endDay": 30
    },
    "winter": {
      "startMonth": 10,
      "startDay": 1,
      "endMonth": 5,
      "endDay": 31
    }
  }
},
"fixedCharges": [
  {
    "chargeType": "SERVICE_CHARGE",
    "description": "Monthly Service Charge",
    "amount": 15.00
  },
  {
    "chargeType": "INFRASTRUCTURE_FEE",
    "description": "Infrastructure Maintenance Fee",
    "amount": 3.50
```

```
    }
  ],
  "calculationRules": {
    "prorationMethod": "DAILY",
    "roundingPrecision": 2,
    "minimumBill": 18.50
  }
}
```

4.6 Tax Calculation

Tax Jurisdictions:

The system supports multi-jurisdictional tax calculation based on service address location. Tax rates are configured by postal code and municipality.

Tax Types:

1. **State Energy Tax:** Applied to total energy charges (not fixed charges)
2. **Local Utility Tax:** Applied to subtotal before taxes (energy + fixed)
3. **Municipal Franchise Fee:** Applied to subtotal, varies by city
4. **Environmental Surcharge:** Fixed amount per kWh

Tax Calculation Algorithm:

For each invoice:

1. Calculate energy_charges_subtotal (all consumption-based charges)
2. Calculate fixed_charges_subtotal (all fixed monthly charges)
3. Calculate subtotal_before_tax = energy + fixed
4. Determine tax jurisdiction from service address postal code

5. Retrieve applicable tax rates for jurisdiction

6. Calculate State Energy Tax:

   state_tax = energy_charges_subtotal × state_tax_rate

7. Calculate Local Utility Tax:

   local_tax = subtotal_before_tax × local_tax_rate

8. Calculate Municipal Franchise Fee (if applicable):

   franchise_fee = subtotal_before_tax × franchise_rate

9. Calculate Environmental Surcharge:

   env_surcharge = total_kwh × per_kwh_surcharge_rate

10. Sum all taxes:

    total_tax = state_tax + local_tax + franchise_fee + env_surcharge

11. Calculate final amount due:

    total_due = subtotal_before_tax + total_tax

Tax Rate Table (Sample):

Postal Code	State Tax	Local Tax	Franchise Fee	Env. Surcharge
4912001-49120 50	3.5%	1.8%	2.0%	$0.0025/kWh
4912051-49121 00	3.5%	1.8%	0%	$0.0025/kWh
4913001-49130 50	3.5%	2.1%	1.5%	$0.0025/kWh

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5. Billing Calculation Engine

5.1 Calculation Sequence

The Billing Calculation Engine processes accounts through a strictly ordered sequence of operations:

Step 1: Account Validation

- Verify account is active and billable
- Check for billing holds or payment plan modifications
- Confirm rate plan assignment is valid for cycle dates

Step 2: Usage Data Retrieval

- Load validated usage record from Usage Data Store
- Verify data completeness for calculation requirements
- Check for special handling flags (estimated, partial cycle, meter change)

Step 3: Rate Plan Application

- Determine effective rate plan for billing cycle
- Load rate configuration and calculation rules
- Handle mid-cycle rate changes if applicable

Step 4: Consumption Calculation

- Apply tier thresholds, TOU periods, or demand calculations per rate plan
- Generate detailed consumption breakdown
- Document which usage falls into each rate category

Step 5: Charge Calculation

- Calculate energy charges by applying rates to consumption
- Add all fixed monthly charges
- Apply any account-specific adjustments or credits

Step 6: Tax Calculation

- Determine tax jurisdiction
- Calculate all applicable taxes and surcharges
- Sum tax amounts

Step 7: Prior Balance Integration

- Retrieve any outstanding balance from previous cycles
- Add late fees if applicable
- Apply any payments or credits received since last bill

Step 8: Invoice Line Item Generation

- Create detailed line items for invoice presentation
- Generate human-readable descriptions
- Calculate running subtotals

Step 9: Audit Trail Creation

- Log complete calculation details
- Store rate plan version used
- Record all inputs and intermediate calculations
- Create immutable audit record for regulatory compliance

5.2 Partial Cycle Billing

Scenario: Customer initiates service mid-cycle or terminates service before cycle end

Calculation Methodology:

For tiered rate plans (like R1):

1. Calculate prorated tier thresholds:

```
prorated_tier1_threshold = 500 × (actual_days / standard_cycle_days)
```

2. Example: 15 days of service in 30-day cycle:

   prorated_tier1 = 500 × (15/30) = 250 kWh

3. Apply prorated thresholds to actual consumption:

   If actual consumption = 180 kWh:

   - Tier 1: 180 kWh (entirely within prorated baseline)

   - Tier 2: 0 kWh

4. Prorate fixed charges:

   prorated_service_charge = $15.00 × (15/30) = $7.50

   prorated_infrastructure_fee = $3.50 × (15/30) = $1.75

For time-of-use plans:

1. No threshold prorations needed

2. Simply apply TOU rates to actual consumption by period

3. Prorate fixed charges based on days of service

Minimum Bill Policy:

Even for partial cycles, a minimum bill applies:

- Residential: Minimum $5.00
- Commercial: Minimum $15.00

This ensures cost recovery for billing operations even for very short service periods.

5.3 Back-Billing and True-Up Calculations

Back-Billing Scenario: Meter malfunction discovered requiring correction of previous bills

Business Rules:

- Maximum back-bill period: 12 months per regulatory requirements
- Customer must be notified before back-bill processing
- Payment plans available for back-bills exceeding $150

Calculation Process:

For each affected billing cycle:

1. Retrieve original bill details from Invoice Archive

2. Calculate correct charges using actual usage data

3. Determine adjustment amount:

   adjustment = correct_charges - original_billed_amount

4. Create adjustment line item on current invoice:

   - Positive adjustment: Additional charge

   - Negative adjustment: Credit to customer

5. Include detailed explanation in invoice notes:

   "Billing Adjustment for [Month Year]: Meter data correction"

True-Up After Estimated Bill:

When actual reading received after estimated bill:

1. Calculate what should have been billed:

   correct_amount = calculate_with_actual_reading()

2. Calculate what was estimated:

   estimated_amount = previous_invoice_total

3. Calculate true-up adjustment:

trueup = correct_amount - estimated_amount

4. Apply adjustment as line item on next invoice:

If trueup > 0: Add "Prior Period Adjustment - Additional Charges"

If trueup < 0: Add "Prior Period Adjustment - Credit"

---

6. Invoice Generation

6.1 Invoice Structure

Each generated invoice contains the following sections:

Header Section:

- Invoice number (unique identifier)
- Customer account number
- Service address
- Billing period dates
- Invoice date
- Payment due date (21 days from invoice date)
- Previous balance (if any)

Current Charges Section:

- Energy consumption line items (by tier or TOU period)
- Demand charges (if applicable)
- Fixed charges (service charge, fees)
- Taxes and surcharges
- Current charges subtotal

Adjustments Section (if applicable):

- Prior period adjustments
- Credits or refunds
- Late payment fees
- Payment plan adjustments

Summary Section:

- Previous balance
- Payments received
- Current charges
- **Total Amount Due**

Usage Comparison Section:

- Current period usage vs. same period last year
- 12-month usage history graph
- Average daily usage comparison

Important Messages:

- Payment options and methods
- Budget billing program information
- Energy efficiency tips
- Customer service contact information

6.2 Invoice Line Item Detail

Example invoice line items for R1 customer with 750 kWh:

CURRENT ELECTRIC CHARGES

Billing Period: Sep 3, 2025 - Oct 2, 2025 (30 days)

Meter Number: MTR-894512-A

ENERGY CHARGES

Tier 1 Usage (0-500 kWh)

500 kWh × $0.1198/kWh $59.90

Tier 2 Usage (>500 kWh)

250 kWh × $0.1498/kWh $37.45

Energy Charges Subtotal $97.35

FIXED CHARGES

Monthly Service Charge $15.00

Infrastructure Maintenance Fee $3.50

Fixed Charges Subtotal $18.50

TAXES AND SURCHARGES

State Energy Tax (3.5%) $4.05

Local Utility Tax (1.8%) $2.09

Taxes Subtotal $6.14

TOTAL CURRENT CHARGES $121.99

Previous Balance $0.00

Payments Received $0.00

TOTAL AMOUNT DUE $121.99

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Payment Due Date: October 23, 2025