FRONTEND MASTER SPECIFICATION v2.1.3

Project: Energy AI Platform (Frontend MVP)

Focus: UI/UX Architecture, Component Contracts, Routing, Data Visualization, and App State

Tech Stack: Next.js (App Router, TypeScript), React Query (stale-while-revalidate), Apache ECharts, Deck.gl / Mapbox GL JS (Nodal Maps), TailwindCSS, Zustand (Global State), Clerk (Auth), Stripe (Billing preparation, disabled until Stripe account exists)

1. Core Architecture & UI Principles

1. **Dashboard-as-Code (JSON Engine):** Dashboards are not hardcoded React pages. They are defined via a JSON schema (layout grid, widgets array, dataset_ids). A central <DashboardRenderer /> maps these JSON objects to React components. This immediately prepares the platform for the "Custom Dashboards" self-service builder.

Identifiers & Naming: The frontend and all URLs use dataset_id as the primary stable identifier. Dashboard JSON definitions reference dataset_id only. Dataset detail responses may additionally include curve_uuid (immutable technical ID) and api_identifier (human readable stable key). Recommended convention: dataset_id equals api_identifier to avoid maintaining two parallel string keys. curve_id remains an internal DB join key and must never be exposed as a frontend dependency.

2. **Chart Template Library (metadata driven): We keep the "Dashboard-as-Code" approach and render charts purely from JSON definitions plus API metadata. Instead of dataset specific code, the Frontend provides a small fixed library of generic chart templates (Line, StackedColumn, StackedColumnPlusLine, AreaPlusLine, GroupedColumns, StackedArea, DualAxisBarLine). Each template reads a declarative visual_config (series roles, chart_type, axis mapping, stack_group, unit tokens) and supports per-dashboard overrides (color_token overrides, axis choice, series visibility). No country or dataset may introduce custom React code.**
3. **Resilience & Partial Success:** A failing dataset or missing permission must *never* crash a dashboard. The renderer enforces error boundaries per widget. If 1 out of 12 widgets fails (e.g., HTTP 403 or 404), 11 render successfully, and the failed widget displays a localized, inline <ErrorCard />.
4. **Time Consistency & Performance: All timestamps are stored and served by the API in strict UTC. The frontend renders in a user selected displayTimezone (global state), default Europe/Berlin (CET/CEST), switchable to Europe/London and UTC. Initial dashboard load target is < 1 second. The UI uses stale-while-revalidate caching and relies on the POST /v1/series/batch API endpoint to prevent network waterfalls.**

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2. Information Architecture & App Shells (Sidebar)

The layout features a fixed left sidebar. Navigation between apps feels instantaneous. Features not fully implemented in MVP Phase 1 are shipped as **UI Shells**. A UI Shell resolves to a valid route and renders a skeleton grid layout featuring a professional "Coming Soon" or "Premium Feature" badge to establish the platform's massive scope immediately.

A. MAIN APPS

- **Dashboards** *(Active: The cascading EU -> Region -> Country entry point)*

- 🛠️ **Custom Dashboards** [UI Shell] *(Prepares for user self-service. Shows an empty grid with an "Add Widget" placeholder button)*
- 📈 **Futures, Fuels & Spreads** [UI Shell]
- ⚡ **Picasso** [UI Shell] *(Placeholder for dedicated aFRR/mFRR Merit Order snapshot curves)*
- ⚖️ **Imbalance Capacity** [UI Shell]
- 🔥 **Gas** [UI Shell]
- 🗺️ **Nodal Analyse** [UI Shell] *(Placeholder for the aggregated matrix/comparison app)*
- 🛒 **Retail** [UI Shell] *(e.g., Tibber-Monitor / Margin tracker)*

B. DATA & TOOLS

- 🔍 **Data Catalog** *(Active: The "Data Explorer" with search, filters, and safe previews)*
- 🏆 **Record Tracker** [UI Shell] *(Highest/Lowest records views)*
- 💡 **Insights** [UI Shell] *(Market commentary / Newsfeed)*
- 🔔 **Alerts** [UI Shell] *(Threshold alerts UI)*
- ⬇️ Export Data (Active: Phase 1 minimal export center, list of exports can be a placeholder. Graph and Dataset exports must work.)

C. UTILITIES & USER (Bottom Left)

- ⭐ **My Grid Status** [UI Shell] *(Saved Views / Favorites)*
- ⌨️ **Jump to... (Ctrl + K)** *(Active: Global command palette for quick API/Dataset search)*
- 🗂️ **All Apps**
- 🚀 Upgrade Now (Active: Highly visible CTA for Basic users. Phase 1: opens an Upgrade modal with plan comparison and a placeholder flow. No Stripe Checkout until Stripe is configured.)
- 💰 **Pricing** | 📖 **Documentation & Blog** | ✉️ **Contact**
- ⚙️ Settings (Active: Plan & Billing placeholder, Usage/Quota tracking, API Keys, Account, Labs, Sign Out. Stripe Customer Portal is disabled until Stripe is configured.)

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3. Account Types & Entitlements UI

The frontend uses Clerk for login and session management to govern UI states. True security, entitlements, and data truncation are enforced by the backend API using plan rules.

1. **Guest (Logged Out):** Sees the landing page and public Insights/Blog. Clicking any data or dashboard triggers the Clerk Login Wall.
2. **Basic (Logged In, Basic tier): Access to the portal and curated dashboards. History is limited to last 6 months (API enforced). Forecast horizon is limited to +2 days (API enforced).**

Exports and API usage are limited (quota enforced). Forecast datasets are hidden in Catalog search and suggest. Premium datasets may appear greyed out and are not clickable.

- Access to EU and Region macro dashboards, and Country dashboards including Today, Trends, Forecast, and History views (with truncation rules above).
- Country dashboards are the same layout across markets. Basic users can open all views, but cannot extend beyond plan limits (date pickers and horizons enforce, and show upgrade CTAs).
- **Truncation Banner (Crucial UX): If a user requests a wider range than their plan allows, the API truncates the response and returns limits_applied: true with applied limits. The widget renders successfully but overlays a persistent banner, for example: "Showing last 6 months. Upgrade to unlock full history."**
- Upgrade CTA and Lock Indicators: Locked premium features show a lock icon and disable interaction (greyed out). If a user tries to exceed Basic limits (history beyond 6 months, forecast beyond +2 days), show an Upgrade modal. No Stripe checkout in Phase 1.

3. **Hobby (Premium): Full access to complete history and complete forecast horizon available in the system. Higher export and API quotas than Basic. Forecast datasets are visible in Catalog search.**
4. **Professional (Premium): Same data access as Hobby, plus higher API and export limits. API key generation and management is enabled in Settings.**
5. **Enterprise: Custom pricing. Includes Raw Bids access (Picasso) and team features.**

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4. Global Dashboard Mechanics & Chart Engine

Every widget rendered in a dashboard must support the following global mechanics:

- **Sync Tooltips:** A global toggle in the dashboard header. When active, Zustand state links all timeseries charts via echarts.connect. Hovering over 14:15 in one chart moves the crosshair to 14:15 in *all* charts simultaneously.
- **Resolution Switcher:** Global toggle allowing users to switch between 15m and 1h granularity for supported widgets.
- **Widget Header Actions (Top Right of every card):**
  - [ ] **Fullscreen:** Opens the chart in an overlay modal.
  - ↓ Download Data: Opens an export window and allows CSV download matching the current visible chart view.
  - </> **View API Code:** Opens a modal showing the exact cURL and Python snippet (with auth placeholders, dataset IDs, and current parameters) needed to reproduce this specific view.
- **AI Context Display:** Tooltips and chart headers must render unit_verbose (natural language units) and ai_expert_note (domain knowledge strings) provided by the metadata.

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5. The Dashboard Hierarchy (Drill-Down Layouts)

Dashboards are curated via JSON definitions but follow a strict hierarchical user journey.

Phase 1 delivers 6 curated dashboards (definitions) that prove scalability: (1) All Countries Overview, (2) Region Overview (CWE, Today), (3) Country Today (DE), (4) Country Trends (DE), (5) Country Forecast (DE), (6) Country History (DE). These six definitions are then replicated for additional markets and regions.

Level 1: Europe Overview Dashboard (/eu)

Macro view focusing on cross-border comparisons.

- **Left Pane (Master Table):**
    - *Rows:* Market zones (countries), grouped and collapsible by regions (e.g., CWE contains DE, BE, NL, CH, AT, FR).
    - *Columns (7-8):* Spot Today, Intraday Price Today, Spot Tomorrow, Relative % Change.
    - *Routing:* Clicking a region -> Level 2. Clicking a country -> Level 3.
- **Right Pane (Nodal Maps Grid):**
    - Grid of 5-6 Deck.gl maps coloring country polygons based on **Daily Averages**.
    - *Global Map Slider:* Bottom slider allows shifting all maps from -2 Days to +2 Days.
    - *Maps:* 1. Spot Price (Today), 2. Main Production Source (Categorical colors, e.g., Wind=Blue, Coal=Black), 3. Consumption (Heatmap high/low), 4. Wind Production, 5. Solar Production.
- **Bottom Pane (EU Macro Charts):**
    1. Line Chart: Avg Prices (15m/1h) per Region.
    2. Line Chart: Top 5 most expensive countries.
    3. Line Chart: Top 5 cheapest countries.
    4. Area Chart: Renewable Share in the EU.
    5. Stacked Area: Aggregated EU Production by source type.
    6. Area Chart: Aggregated EU Consumption.

Level 2: Region Overview Dashboard (e.g., /eu/cwe)

Focuses on the interconnectivity of a specific cluster.

- **Top Left (Region Table):** The 6 countries. 2 rows per country for compact display. Columns: Spot Today, Spot Tomorrow, Current Intraday, High/Low context, %.
- **Top Right (Regional Nodal Heatmap):** Interpolated Deck.gl heatmap built from the 3,200 EU weather points. Visualizes geographic clusters of generation/weather, not individual hard markers. Dropdown toggles: Wind, Solar, Temperature.
- **Bottom Pane (Region Charts):**
    1. Line Chart: Spot prices of the 6 countries.

2. Line Chart: Intraday prices of the 6 countries.
3. Stacked Area: Total consumption of the region.
4. Combo Area/Line: Wind production of the 6 countries.
5. Combo Area/Line: Solar production of the 6 countries.
6. Mixed (Bar+Line): UMMs (Bar: Outage MW volume, Line: Volume change).

Level 3: Country Dashboard (e.g., /eu/cwe/de)

*The detailed daily operations view. Features a **Tab Navigation** altering the global Time-State. The 11-row layout remains completely identical across all tabs; only the time parameters, API calls, and Map slider behaviors change.*

A. The 4 Time-State Tabs:

1. **Today (Default):** Displays 00:00 - 23:59 of the selected day. Datepicker selects single historical days. *Nodal Map Slider resolves in 15-minute increments.*
2. **3-Day Trends:** Displays Yesterday, Today, Tomorrow. Sync-tooltips operate seamlessly across the 72h window. (Fallback if no Tomorrow data: D-2, D-1, Today).
3. **Forecast (Plan limited): Displays Yesterday, Today, and future days. Basic shows up to +2 days, Premium shows the complete forecast horizon available for the datasets. Nodal Map switches to daily-average heatmaps, and the slider moves in increments of Days.**
4. **History (Plan limited): Custom Date-Range picker (defaults 2 or 4 weeks). Basic can access up to last 6 months. Premium can access full history. For performance, high resolution selection is limited, wider ranges automatically request downsampled resolution from the API.**

B. Top Row (7 KPI Stat Cards):

1. Current Load | 2. Current Residual Load | 3. Main Prod Source | 4. Current System Imbalance | 5. Current Imbalance Price | 6. Current Intraday Price | 7. Grid Transparency Traffic Light (DE specific).

C. The 11-Row Chart Grid (Using Chart Templates):

- **Row 1 (Prices & Map):**
    - *Left (Line Chart):* DA Price vs. Intraday vs. Imbalance vs. ID500 (IDAEP). Switchable 15m/1h.
    - *Right (Nodal Map):* Country bounds. Dropdown: Wind Prod, Wind Speed, Solar, Temp, Precipitation. Slider controlled by Time-State Tab.
- **Row 2 (Consumption):** Combo Chart - Day-Ahead Consumption (Line) vs. Actual Consumption (Area).
- **Row 3 (Imbalance):** Dual-Axis Chart - System Imbalance (Line) vs. Balancing Energy Activations by type (Stacked Bars).
- **Row 4 (Residual Load):** Combo Chart - Residual Load Day-Ahead (Line) vs. Actual (Area).

- **Row 5 (Wind):** Combo Chart - Actual Wind On/Offshore (Stacked Area) vs. DA Wind On/Offshore (Lines).
- **Row 6 (Solar):** Combo Chart - Actual Solar (Area) vs. DA Solar (Line).
- **Row 7 (Hydrology):** Stacked Area - Reservoir, Pumped Storage, Run-of-River.
- **Row 8 (Flows):** Combo Chart - Exchange Commercial Flow (Stacked Area) vs. Physical Flow (Line).
- **Row 9 (Production Mix):** Stacked Area - Total production mapped by primary source (Wind, Coal, Nuclear, Solar, Lignite, etc.).
- **Row 10 (UMMs):** Dual-Axis Chart - UMMs Production Outages (Stacked Bars by MW/Type) vs. Total UMM Change to Yesterday (Line).
- **Row 11 (Redispatch):** Stacked Area or Bar (driven by visual_config) - Redispatch volumes.

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6. Specialized UI Capabilities & Discovery

A. Data Explorer & Catalog (Discovery UX)

The /catalog route is a daily entry point for B2B API discovery.

Catalog Entitlements: For Basic users, forecast datasets are not returned by /v1/catalog/suggest and are hidden from Catalog search results. Other premium-only datasets may be returned but must render as greyed out results with a lock icon and disabled click. For Premium users, all datasets are shown and clickable according to API permissions.

- **Search Layout:** Two-pane view. Left pane: Search input (debounced 200ms), facet filters (dataset_type, region, source, access tier), and a virtualized results list. Right pane: Live preview.
- **Dataset Pages (/datasets/[id]):** Single source of truth.
    - *Header:* Metadata, badges, update frequency, driver links.
    - *Preview:* Safe-window chart preview + paginated raw data table.
    - *Mandatory Actions:* "Add to Dashboard" (Generates JSON snippet) and "View API Code" (Dynamic panel generating snippets based on preview state).

B. Snapshot Curves (Picasso / Bid Curves)

Datasets flagged as snapshot_curve require a specialized React component (<SnapshotCurveChart />).

- **Visuals:** Supports segments (horizontal MW blocks) and line_step views.
- **Time Selector:** Bypasses global dashboard time ranges. Uses a distinct **Slot Picker** dropdown (querying the /available_times endpoint). Defaults to the "latest" slot.

C. Future App Prep (UI Shell Architecture)

- **Nodal Analyse App:** Dedicated to calculated matrix averages and region comparisons. Top bar selectors for Target Dataset, Window (Rolling 365, Current Year), and Matrix Type. Main Panel for Month-by-Hour Heatmaps.

- **Record Tracker App:** Offline computed records. Renders a list of record cards (e.g., "Highest daily average"). Clicking a card deep-links to the Dataset Page with pre-filled time ranges.

ADDENDUM: FRONTEND MASTER SPECIFICATION v2.1.3

Topic: Real-Time Mechanics, Timezone Management & Payload Optimization

This addendum extends the FRONTEND MASTER SPECIFICATION v2.1.3 with the following strict architectural rules:

1. Timezone Management (UTC to CET):

- All raw data arrives from the API in strict UTC.
- The frontend uses a global Timezone State (Zustand), defaulting to **CET/CEST (Europe/Berlin)**.
- All ECharts X-axes, tooltips, and data tables must dynamically convert UTC timestamps to the selected timezone before rendering to the user.
- *Future Prep:* The UI includes a timezone dropdown placeholder in the header to switch to UK Time (Europe/London) or UTC later.

2. Real-Time Polling (Auto-Refresh):

- To support volatile markets (e.g., Imbalance, Intraday), the frontend implements background polling.
- Dashboards auto refresh: Only views that include now or end within the last 6 hours auto refresh. Default refetchInterval is 180 seconds for Today and Trends. Forecast refresh every 600 seconds. History does not auto refresh. Auto refresh pauses when the tab is not visible.

Polling Rules: (1) Today view, refresh 180s when selected day is today, otherwise no polling. (2) Trends view, refresh 180s when window includes today, otherwise no polling. (3) Forecast view, refresh 600s when it includes today, otherwise no polling. (4) History view, no polling. (5) Catalog preview, no polling, only fetch on selection or parameter change.

3. History Data Constraints & Downsampling:

- To prevent browser memory crashes on long history views, the custom Date Range Picker is limited to a maximum selection of **3 months** for high-resolution (15-minute) raw data.
- If a user requests a wider range, the frontend must dynamically request a downsampled resolution (e.g., resolution: '1d' or '1h') from the API.

4. Payload Optimization & Pre-Calculated Data:

- *EU Tables:* The frontend must *never* download massive timeseries arrays just to calculate table averages. The API must deliver pre-calculated metrics (e.g., Daily Averages) and context strings (e.g., *"20% higher than Seasonal Normal"*) directly.
- *Nodal Map Matrix (60fps Performance):* For the Country/Region 15-minute maps (up to 3,200 points), the frontend *cannot* make an API call every time the slider moves. On initial load, the API will send a compressed matrix containing **all 96 intervals for all points at once**. The