## **AI-Powered Digital Twin for Energy Planning: Detailed UI/UX & Data Visualization Guide for Designers**

This document provides a detailed UI structure, UX flow, placeholder data examples, and visualization guidance for each step of the Digital Twin platform. It is intended to help UI designers with no prior domain knowledge to create mockups and prototypes.

**Overall Platform Principles:**

* **Clarity & Simplicity:** Assume the user is a planner, not necessarily a data scientist. Avoid jargon where possible, or provide tooltips.
* **Visual First:** Prioritize maps, charts, and dashboards to convey information.
* **Guided Workflow:** The UI should naturally guide the user through the planning steps.
* **Responsiveness:** Ensure the design adapts well to typical desktop screen sizes.

### **1. Home Screen**

* **What the User Sees:**
  + **Header:** Platform Title: "Energy District Planner AI", Logo (e.g., a stylized building with a leaf or energy symbol).
  + **Role Selection Section:**
    - **Headline:** "Select Your Role:"
    - **Cards/Icons (Horizontally arranged, selectable):**
      * [Card 1: Grid Operator] (Icon: transformer/pylon). Theme: Blue/Steel.
      * [Card 2: Urban Planner] (Icon: city skyline/map). Theme: Green/Earth Tones.
      * [Card 3: Policy Maker] (Icon: graph chart/briefcase). Theme: Purple/Gold.
      * [Card 4: Building Physics Expert] (Icon: blueprint/gear). Theme: Orange/Grey.
      * [Card 5: Building Owner] (Icon: house/key). Theme: Teal/Sand.
      * [Card 6: General User] (Icon: user silhouette/compass). Theme: Default/Neutral.
    - **Instruction:** "Select a role to tailor your experience (currently themes your interface)." One card must be visually highlighted as selected (e.g., brighter border, shadow).
  + **Welcome Section:**
    - Headline: "Welcome to the Future of Energy Planning"
    - Sub-headline: "Leverage AI and Digital Twins to design sustainable and resilient energy districts."
  + **Main Navigation Call-to-Actions (Large, clear cards or buttons below role selection):**
    - Card 1: "Start New Planning Project" (Icon: plus symbol or map pin).
    - Card 2: "Load Existing Project" (Icon: folder open).
    - Card 3: "What is a Digital Twin?" (Icon: question mark).
  + **Optional Visual:** A subtle, attractive background image or graphic related to smart cities or sustainable energy, which might subtly change with role selection.
  + **Footer:** Links: "About Energy District Planner AI," "Help & Documentation," "Contact Support," "Terms of Service," "Privacy Policy."
* **Buttons & Interactive Elements:**
  + Role Selection Cards (Clickable).
  + [Button/Card: Start New Planning Project]
  + [Button/Card: Load Existing Project]
  + [Button/Card: What is a Digital Twin?]
* **Happenings (User Interactions):**
  + **User clicks a Role Card (e.g., "Urban Planner"):**
    - The selected card becomes highlighted.
    - The overall UI theme/color scheme subtly changes (e.g., accent colors, background highlights change to green/earth tones). No change in workflow or available options for now.
  + Clicking Start New Planning Project: Takes the user to the "District Selection" page. The system is ready for a new planning session.
  + Clicking Load Existing Project:
    - **UI Change:** A modal window appears titled "Load Project."
    - **Fake Data for Modal:** A list of 2-3 fake project names:
      * "North District - 2040 Electrification Plan" (Last Saved: 2 days ago)
      * "City Center - Retrofit Initiative" (Last Saved: 1 week ago)
      * "Industrial Park - PED Feasibility" (Last Saved: 1 month ago)
    - **Modal Elements:** Each project has an "Open" button and a "Delete" icon. A "Cancel" button is also present.
    - **Interaction:** Clicking "Open" on a project loads its data and takes the user to the relevant stage (e.g., "Scenario Comparison Dashboard" if it's a completed plan, or "Intervention Selection" if it's a work-in-progress).
  + Clicking What is a Digital Twin?:
    - **UI Change:** A modal info box appears titled "What is a Digital Twin?"
    - **Fake Data for Modal (Bullet points):**
      * A Digital Twin is a virtual replica of a physical asset, process, or system.
      * It uses real-world data to simulate, predict, and optimize performance.
      * In energy planning, it helps test 'what-if' scenarios for districts without real-world risk.
      * Enables data-driven decisions for retrofits, renewable integration, and grid upgrades.
      * Fosters collaboration between different stakeholders.
    - **Modal Elements:** "Close" button.

### **2. District Selection → Data Overview**

#### **2.1. Page: District Selection**

* **What the User Sees:**
  + **Page Title:** "Step 1: Select Your District"
  + **Interactive Map (e.g., OpenStreetMap base layer):**
    - **Fake Data:** Display 3-5 clearly defined, differently shaped polygonal areas representing districts (e.g., "Northwood District," "Downtown Core," "Riverside Community"). These should be visually distinct. When hovered, a district polygon highlights.
  + **Search Bar:** Placeholder text: "Search by district name or postcode..."
  + **District List (Scrollable):**
    - **Fake Data:**
      * "Northwood District" (Region: North, Buildings: ~1,200)
      * "Downtown Core" (Region: Central, Buildings: ~850)
      * "Riverside Community" (Region: West, Buildings: ~600)
      * "East Industrial Zone" (Region: East, Buildings: ~150)
  + **Information Panel (Initially empty or showing helper text "Select a district to see details"):**
    - When a district is selected:
      * District Name: "[Selected District Name]"
      * Region: "[Region]"
      * Approx. Number of Buildings: "[Number]"
      * Brief Description: "A mixed-use urban area with residential and commercial zones." (Fake generic description)
      * [Button: Load District Data & View Overview] (becomes active).
* **Buttons & Interactive Elements:**
  + Map: Clicking on a district polygon selects it.
  + District List: Clicking a list item selects it.
  + [Button: Load District Data & View Overview] (Initially disabled. Becomes active once a district is selected).
* **Happenings (User Interactions):**
  + **User clicks a district on map OR list:**
    - The selected district is visually highlighted (e.g., thicker border, different fill color on map; highlighted row in list).
    - The Information Panel populates with the selected district's basic fake data.
    - The Load District Data & View Overview button becomes enabled.
  + **User types "North" in search bar:**
    - The District List filters to show only "Northwood District."
    - The map might zoom/pan to focus on "Northwood District."
  + **Clicking Load District Data & View Overview:**
    - The system "loads" the selected district's data (show a brief loading spinner icon).
    - Navigates to the "Data Overview" page (Section 2.2) for the chosen district.

#### **2.2. Page: Data Overview (e.g., for "Northwood District" after selection)**

* **What the User Sees:**
  + **Page Title:** "Data Overview: Northwood District"
  + **Layout:** A dashboard-style page with several sections.
  + **Section 1: Key Metrics/KPI Cards (Row of 4, visually distinct cards with icons):**
    - **Fake Data:**
      * Card 1: "Buildings Count": "10" (actually use the count for the selected district, e.g., "1,234") (Icon: building)
      * Card 2: "Avg. Monthly Demand (District)": "650 kWh" (per building average or total, clarify) -> "Total Est. Monthly Demand: 800 MWh" (Icon: lightning bolt)
      * Card 3: "Grid Health Summary": "1 Transformer At Risk (>80% Load)" (Icon: alert/shield)
      * Card 4: "Local Generation Share": "20% (PV, Battery)" (Icon: solar panel/battery)
  + **Section 2: Energy Demand & Sources Visualizations:**
    - **Bar Chart (Left): Monthly Energy Demand**
      * Title: "Monthly Energy Demand (MWh)"
      * Fake Data: Jan (950), Feb (1050), Mar (800), Apr (700), May (600), Jun (500), Jul (550), Aug (580), Sep (650), Oct (750), Nov (900), Dec (1100). (Illustrates seasonal variation).
      * Visualization: Vertical bars for each month (Jan-Dec). Y-axis: MWh.
    - **Pie Chart (Right): Energy Sources (Annual Baseline)**
      * Title: "Annual Energy Sources"
      * Fake Data: "Grid Import: 80%", "Local Solar PV: 18%", "Local Battery Discharge: 2%".
      * Visualization: Slices with distinct colors, labels, and percentages.
  + **Section 3: District Map View (Interactive Mini-Map):**
    - Title: "District Asset Overview"
    - **Fake Data & Visualization:**
      * A simplified map of the selected district.
      * Buildings (dots/small squares): Default color grey. 5-10 buildings are **blue** (labeled "Retrofitted"). 5-10 buildings are **red** (labeled "Non-Retrofitted - High Demand").
      * Transformers (triangles): 2-3 transformers. One is **red** (High Load), one **yellow** (Medium Load), one **green** (Low Load). Hovering shows "ID: T-01, Load: 85%".
      * PV Installations (small lightning/sun icons): 3-4 **yellow** icons on some building rooftops or small areas.
      * Battery Storage (small battery icons): 1-2 **purple** icons near transformers or commercial buildings.
  + **Section 4: Asset Tables (Tabbed or side-by-side if space allows):**
    - **Tab/Table 1: Grid Assets**
      * Title: "Key Grid Assets"
      * Columns: Name, Type, Loading (%), Status (Icon + Text)
      * **Fake Data:**
        + "Transformer Alpha", "Transformer", "85%", "⚠️ At Risk" (Yellow icon or text)
        + "Transformer Beta", "Transformer", "50%", "🟢 Healthy" (Green icon or text)
        + "Feeder F-01A", "Feeder", "65%", "🟢 Healthy"
        + "Substation North", "Substation", "N/A", "🟢 Healthy"
    - **Tab/Table 2: Sample Buildings Overview**
      * Title: "Sample Buildings Snapshot"
      * Columns: Building ID, Construction Year, Area (m²), Est. Demand (kWh/mo), Retrofit Status, EV Charger?, PV Capacity (kWp)
      * **Fake Data (3-4 rows):**
        + "NB-0112", 1960, 120, 850, "No", "Yes", 0
        + "NB-0345", 1995, 250, 600, "Yes (Deep)", "No", 5
        + "CB-007", 2010, 1500, 2500, "Partial", "Yes (Shared)", 20
* **Buttons & Interactive Elements:**
  + Map interactions (hover on assets for basic tooltips).
  + Table interactions (sorting).
  + [Button: Explore Detailed Data]
  + [Button: Configure New Scenario]
  + [Button: Back to District Selection] (Return to Section 2.1 to pick a different district).
* **Happenings (User Interactions):**
  + User reviews the comprehensive snapshot of the selected district.
  + Clicking Explore Detailed Data: Navigates to the "Detailed Data Exploration" page (Section 3) for more in-depth analysis of the *same* selected district.
  + Clicking Configure New Scenario: Skips detailed exploration and navigates directly to "Scenario Configuration" (Section 4) for the *same* selected district.

### **3. Detailed Data Exploration**

* **What the User Sees:**
  + **Page Title:** "Detailed Data Exploration: Northwood District"
  + **Main Layout:** A large interactive map on one side (e.g., left 60%), and a tabbed panel for details/tables/charts on the other (e.g., right 40%).
  + **Map View:**
    - **Default Layer:** Building footprints.
    - **Fake Data:** ~50-100 sample building footprints of varying sizes and shapes within the district boundary.
    - **Interaction:** Clicking a building on the map highlights it and populates the "Building Details" tab in the side panel.
  + **Side Panel (Tabbed):**
    - **Tab 1: Building Details (Active by default or when a building is clicked on map):**
      * **Fake Data (for a selected sample building):**
        + Building ID: "NB-0753"
        + Address: "123 Main St, Northwood"
        + Type: "Residential - Apartment Block"
        + Construction Year: "1975"
        + Number of Floors: "5"
        + Gross Floor Area: "2,500 m²"
        + Estimated Annual Heating Demand: "150 MWh"
        + Attached Sensor ID: "Sensor-A4B7" (if applicable, otherwise "N/A")
      * **Visualization:** A small static image placeholder for a building photo.
    - **Tab 2: Buildings Table:**
      * **Fake Data:** A table with 10-15 rows, columns: Building ID, Type, Construction Year, Floor Area, Est. Demand. Sortable and filterable.
      * **Interaction:** Clicking a row highlights the building on the map and populates the "Building Details" tab.
    - **Tab 3: Grid Infrastructure:**
      * **Map Layers (Toggleable):**
        + "Electrical Feeders" (different colored lines).
        + "Transformers" (point symbols, e.g., squares).
        + "Substations" (larger point symbols, e.g., circles).
      * **Fake Data:** A few sample feeders, 5-10 transformers, 1-2 substations overlaid on the map. Clicking an asset shows its properties in a popup/tooltip (e.g., Transformer ID, Capacity, Current Load %).
    - **Tab 4: Energy Data Visualizations:**
      * **Chart 1: District Hourly Load Profile (Line Chart - Baseline):**
        + Fake Data: A typical daily load curve for 24 hours, showing peaks in morning and evening. Y-axis: Power (MW), X-axis: Hour of Day.
        + Visualization: Smooth line graph.
      * **Chart 2: Building Construction Year Distribution (Histogram):**
        + Fake Data: Ranges like "<1945", "1946-1970", "1971-1990", "1991-2010", ">2010". Show varying counts for each.
        + Visualization: Bars representing the number of buildings in each age bracket.
* **Buttons & Interactive Elements:**
  + Map: Pan, zoom, click on building/grid features. Layer toggle controls for grid elements.
  + Side Panel: Tab selection. Table sorting/filtering.
  + [Button: Proceed to Scenario Configuration]
  + [Button: Back to Data Overview] (Returns to Section 2.2).
* **Happenings (User Interactions):**
  + User clicks a building on the map: Its details appear in the "Building Details" tab.
  + User sorts the "Buildings Table" by "Construction Year": The table reorders.
  + User toggles on the "Transformers" layer: Transformer symbols appear on the map.
  + The page serves as an interactive data deep-dive, allowing users to understand the specifics of the chosen district before planning.

### **4. Scenario Configuration**

* **What the User Sees:**
  + **Page Title:** "Step 2: Configure Scenario for Northwood District"
  + **Form-Based Interface with Collapsible Sections:**
    - **Section 1: Scenario Details:**
      * [Text Input: Scenario Name] (Placeholder: "e.g., Northwood Electrification 2040") - Required.
      * [Text Area: Scenario Description] (Placeholder: "Optional: Describe goals and assumptions...")
    - **Section 2: Baseline & Horizon:**
      * [Read-only Text: Using "Northwood District - Current State 2025" as baseline.]
      * [Dropdown/Slider: Start Year] (Default: 2025)
      * [Dropdown/Slider: End Year] (Default: 2040, options: 2030, 2035, 2040, 2045, 2050)
    - **Section 3: District Policy Targets (Read-Only Information Panel):**
      * Title: "Current District Policy Targets for [Selected District Name]"
      * **Fake Data (Examples for Northwood District):**
        + "Overall CO2 Reduction by 2040 (vs 2020): -70%"
        + "Renewable Energy Share in Buildings by 2035: 50%"
        + "Mandatory Energy Label B for all rentals by 2030."
      * This section informs the user of existing commitments that scenarios should ideally align with or contribute towards.
    - **Section 4: Global Scenario Assumptions & Parameters (Initially collapsed except for "Technology Adoption"):**
      * **Sub-Section 4.1: Technology Adoption Rates:**
        + [Slider: Heat Pump Adoption Target by End Year (% of suitable buildings)] (Default: 50%, Range: 0-100%)
        + [Slider: Electric Vehicle (EV) Penetration Target by End Year (% of households)] (Default: 40%, Range: 0-100%)
        + [Link: Advanced Adoption Curves] (Opens modal for year-by-year input).
      * **Sub-Section 4.2: Economic Factors:**
        + [Input Field: Electricity Price (€/kWh)] (Default: 0.25)
        + [Input Field: Carbon Tax (€/tonne CO2)] (Default: 50)
        + [Input Field: Discount Rate (%)] (Default: 5)
      * **Sub-Section 4.3: Overall Scenario Targets (User Defined Overrides/Goals):**
        + [Input Field: Desired CO2 Emissions Reduction by End Year (vs. Baseline %)] (Default: 60%, Tooltip: "Define a target for this specific scenario, may differ from official policy.")
        + [Checkbox: Aim for Net-Zero Energy for all new constructions in this scenario] (Default: Unchecked)
    - **Section 5: Feasibility Constraints for This Scenario (Editable, with sensible defaults):**
      * Title: "Define Feasibility & Roll-out Constraints"
      * [Slider/Input: Annual Building Retrofit Rate (% of total building stock per year)] (Default: 2%, Range: 0.5% - 10%. Tooltip: "Max % of buildings that can realistically be retrofitted each year.")
      * [Slider/Input: Max DER Penetration (% of technical potential for district)] (Default: 80%, Tooltip: "e.g., Max % of suitable rooftops for PV, or max % of demand manageable by batteries.")
      * [Input Field: Annual Grid Upgrade & NWA Investment Cap (€)] (Default: 500,000. Tooltip: "Maximum budget available per year for all grid-related investments including NWAs.")
* **Buttons & Interactive Elements:**
  + All form elements (inputs, sliders, dropdowns, checkboxes).
  + Accordion behavior for collapsible sections.
  + [Button: Save Scenario Setup & Proceed] (Enabled when scenario name is filled).
  + [Button: Reset to Defaults]
  + [Button: Back to Detailed Data Exploration]
* **Happenings (User Interactions):**
  + User names scenario "High Ambition 2050." Sets End Year to 2050.
  + User reviews the read-only District Policy Targets.
  + User sets "Heat Pump Adoption" to 80%, "Desired CO2 Reduction" to 90%.
  + User expands "Feasibility Constraints" and changes "Annual Building Retrofit Rate" to 3%.
  + Clicking Save Scenario Setup & Proceed: System saves all parameters. Navigates to "Intervention Selection & Definition."

### **5. Intervention Selection & Definition**

* **What the User Sees:**
  + **Page Title:** "Step 3: Define Interventions for Scenario: High Ambition 2050"
  + **Contextual Information Display (Top of Page):**
    - Small panel showing key targets/constraints from Section 4: "Target CO2: 90%", "Max Retrofit Rate: 3%/yr", "Annual Budget: €500k".
  + **Layout:** Three main columns:
    - **Column 1 (Left - Intervention Library/Palette):**
      * Title: "Intervention Library"
      * **List of Expandable Cards (Intervention Types):**
        + [Card: Building Retrofits +] (Icon: wrench/insulation)
        + [Card: Solar PV Deployment +] (Icon: sun)
        + [Card: Battery Storage +] (Icon: battery)
        + [Card: EV Chargers +] (Icon: EV plug)
        + [Card: Demand Response Programs +] (Icon: flexible load)
        + [Card: Grid Upgrades +] (Icon: pylon/transformer)
      * Clicking the + or card title expands it inline or loads its specific settings into Column 2.
    - **Column 2 (Center - Configuration Area for Selected Intervention Type):** This area is dynamic.
      * **Default/Initial State:** Helper text: "Select an intervention type from the library to configure it."
      * **When "Building Retrofits" card is expanded/selected:**
        + **Title:** "Configure Building Retrofits"
        + [Multi-Select Dropdown/Checkboxes: Select Buildings] (Options: "All," "Residential," "Commercial," "Pre-1980," "Most Energy Intensive (Top 20%)" (default), "Select on Map"). Tooltip: "Choose which buildings to target."
        + [Slider: % of Selected Buildings to Retrofit this Phase] (0-100%). Default: 100%.
        + [Dropdown: Retrofit Package] (Fake Data: "Basic Insulation," "Medium Retrofit," "Deep Energy Retrofit"). Tooltip: "Estimated demand reduction: 15-30%."
        + [Input: Target Completion Year for this Phase] (e.g., 2030).
        + [Button: Add This Retrofit Phase to Plan]
      * **When "Solar PV Deployment" card is expanded/selected:**
        + **Title:** "Configure Solar PV Deployment"
        + [Multi-Select Dropdown/Checkboxes: Select Buildings/Areas for PV] (Options: "All Suitable Rooftops," "Commercial Rooftops," "South-Facing Residential," "Select on Map for Community Solar Area").
        + [Dropdown/Input: Size per Building/Area] (Options: "Optimize for Roof," "5kW," "10kW," "20kW," or input kW for area).
        + [Read-only Text: Total New PV Capacity Added This Phase: XX kW] (Auto-calculates).
        + [Input: Target Completion Year for this Phase]
        + [Button: Add This Solar PV Phase to Plan]
      * **When "Battery Storage" card is expanded/selected:**
        + **Title:** "Configure Battery Storage"
        + [Dropdown: Select Location Type] ("At Substation," "Community Hub," "Individual Large Buildings"). Map selection tool or list of substations/buildings.
        + [Slider/Input: Battery Size (kWh)] (e.g., 100-500 kWh).
        + [Slider/Input: Power Rating (kW)]
        + [Input: Target Completion Year for this Phase]
        + [Button: Add This Battery Phase to Plan]
      * **When "EV Chargers" card is expanded/selected:**
        + **Title:** "Configure EV Chargers"
        + [Slider/Input: Number of Charging Points to Add] (e.g., 1-50).
        + [Multi-Select Dropdown/Checkboxes: Select Buildings/Locations for Chargers] (e.g., "Public Parking Lots," "Commercial Buildings," "Residential Complexes," "Select on Map").
        + [Input: Target Completion Year for this Phase]
        + [Button: Add This EV Charger Phase to Plan]
      * **When "Demand Response" card is expanded/selected:**
        + **Title:** "Configure Demand Response Program"
        + [Toggle Switch: Enable Demand Response Program for this Scenario] (Default: Off).
        + If On: [Multi-Select Dropdown/Checkboxes: Select Participating Buildings/Sectors] (Options: "All Eligible Commercial," "Industrial Sector," "Large Residential Complexes").
        + [Input: Target Completion Year for Program Rollout]
        + [Button: Update DR Program in Plan]
    - **Column 3 (Right - Intervention Summary Panel for Current Scenario):**
      * Title: "Current Intervention Plan for 'High Ambition 2050'"
      * **Table (or list of cards):**
        + Columns: Phase/Year, Intervention Type, Target Group, Details, Est. Cost, Actions.
        + **Fake Data (Example after several phases added):**

2028, "Retrofit", "Most Energy Intensive (1st Batch - 20%)", "Deep Retrofit", "€2.1M", [Icon: Edit][Icon: Delete]

2030, "Solar PV", "Commercial Rooftops (Phase 1)", "250 kW total", "€200k", [Icon: Edit][Icon: Delete]

2030, "EV Chargers", "Public Parking Downtown", "10 Chargers", "€50k", [Icon: Edit][Icon: Delete]

2032, "Battery", "Substation North", "250kWh/100kW", "€150k", [Icon: Edit][Icon: Delete]

* + - * **Running Total Feasibility Check:** Small text below summary: "Current Plan: Retrofit Rate: 2.5%/yr (Max: 3%). Max Annual Spend: €450k (Cap: €500k)." (Text turns red if cap exceeded).
* **Buttons & Interactive Elements:**
  + Expandable cards in Column 1.
  + All dynamic form controls in Column 2.
  + Add This ... Phase to Plan buttons in Column 2.
  + Edit/Delete icons in Column 3 summary.
  + [Button: Validate Full Intervention Plan] (Optional: runs a more thorough check against all constraints).
  + [Button: Save Full Plan & Proceed to Simulation] (Bottom of Column 3).
  + [Button: Back to Scenario Configuration] (Bottom of page).
* **Happenings (User Interactions):**
  + User clicks "Building Retrofits +" in Column 1. Column 2 updates to show retrofit configuration options.
  + User selects "Most Energy Intensive" buildings, 50% for this phase, "Deep Energy Retrofit," target year 2028. Clicks Add This Retrofit Phase to Plan. The intervention appears in Column 3's summary. The "Running Total Feasibility Check" updates.
  + User then clicks "Solar PV +" in Column 1. Column 2 changes to Solar PV settings. User defines a PV deployment.
  + If an intervention definition causes a feasibility constraint (e.g., annual budget) to be exceeded, the "Running Total Feasibility Check" text might turn red, and a warning icon appears next to the problematic phase in the summary.
  + Clicking Save Full Plan & Proceed to Simulation: System saves the entire phased intervention plan. Navigates to "Run Demand & Generation Simulations."

### **6. Run Demand & Generation Simulations**

* **What the User Sees:**
  + **Page Title:** "Step 4: Run Simulation for Scenario: High Ambition 2050"
  + **Confirmation Summary (Read-only list or cards):** (Same as before)
  + **Simulation Details:** (Same as before)
  + **Estimated Simulation Time:** (Same as before)
  + **Conceptual Module Status / API Connection Indicator (New):**
    - A small, unobtrusive section perhaps in the footer or a corner of the progress view (once simulation starts) could visually indicate activity:
      * "UBEM Engine: [Green Dot] Connected, Simulating..."
      * "Grid Model API: [Green Dot] Connected, Calculating..."
      * "Data Aggregator: [Yellow Dot] Processing..."
      * This is more for a sense of ongoing processes than direct interaction.
* **Buttons & Interactive Elements:** (Same as before)
* **Happenings (User Interactions):** (Same as before, but the progress text would be more detailed reflecting the multi-year, multi-intervention simulation).

### **7. Grid Impact Analysis & Visualization**

(No changes from the previous detailed version, as your new input focused on Sections 4 & 5. The existing detailed KPI cards, map with time slider, and trajectory charts are still relevant.)

### **8. Knowledge Graph (KG) Integration & Processing Module**

* **Page Title:** "Knowledge Graph Management: [Selected District Name]"
* **Conceptual Overview:** This page represents the (largely automated) backend process of KG creation and updating. It's less about direct user manipulation of the KG and more about transparency into its status and the data it integrates.
* **What the User Sees:**
  + **Section 1: KG Status & Summary:**
    - **Card 1: "KG Status":** "[Green Dot] Operational & Up-to-Date" or "[Yellow Dot] Synchronizing..." or "[Red Dot] Error - Stale Data"
    - **Card 2: "Total Entities":** "15,780" (Fake data: buildings, grid assets, sensors, relationships)
    - **Card 3: "Relationship Types":** "25" (e.g., connectedTo, hasSensor, partOfFeeder)
    - **Card 4: "Last Update":** "June 7, 2025, 02:15 AM"
  + **Section 2: Data Ingestion Pipeline (Visual Flowchart Style):**
    - **Input Sources (Left Side - list with status icons):**
      * "GIS Building Data": [File Icon] buildings.geojson - [Green Check] Last Processed: June 6
      * "DSO Grid Topology": [API Icon] DSO API Endpoint - [Green Check] Last Synced: June 7 (Live)
      * "UBEM Simulation Output (Scenario: High Ambition)": [DB Icon] scenario\_results\_db - [Green Check] Last Processed: June 7
      * "Real-time Sensor Feeds (Optional)": [Stream Icon] IoT Platform - [Yellow Dash] Active / Partially Integrated
    - **Processing Steps (Center - stylized boxes with arrows):**
      * [Box: Data Cleaning & Validation] -> [Box: Semantic Mapping (Ontology Alignment)] -> [Box: RDF Triple Generation] -> [Box: KG Population/Update]
      * Each box could have a sub-text like "Processed 1234 building entities" or "Generated 50000 triples."
    - **Output (Right Side):**
      * [Large Icon: Knowledge Graph Symbol] - "District KG for 'Northwood'"
      * [Link: View KG Schema/Ontology] (Opens a diagram or text definition of the ontology used – for expert users).
  + **Section 3: KG Health & Quality Metrics (Optional - for advanced users):**
    - **Chart 1: Entity Count by Type (Bar Chart):** Buildings, Transformers, Feeders, PV Systems, etc.
    - **Metric: "Data Completeness":** "85% (Weighted average across entity types)"
    - **Metric: "Consistency Checks Passed":** "99.8%"
  + **Section 4: Recent Activity Log (Scrollable List):**
    - **Fake Data:**
      * "INFO: Added 5 new EV Charger entities from 'High Ambition 2050' scenario." (June 7, 02:10 AM)
      * "INFO: Updated load status for 15 Transformers from DSO API." (June 7, 02:00 AM)
      * "WARN: 3 Buildings from GIS data missing construction year." (June 6, 11:00 PM)
* **Buttons & Interactive Elements:**
  + [Button: Force Re-sync All Data Sources] (Admin/Expert feature, with confirmation).
  + [Button: View Data Source Details] (Next to each input source, opens modal with path/API info, last sync details).
  + [Button: View KG Query Interface] (Navigates to an expert SPARQL endpoint or simplified query builder – advanced feature, could be hidden for general users).
* **Happenings (User Interactions):**
  + This page is primarily informational. The user observes the status of the KG.
  + An expert user might click Force Re-sync if they suspect data is stale.
  + The visualization of the pipeline gives confidence that raw and generated data are being correctly processed and integrated into the KG, which then powers other modules like GNN and RL. The "UBEM Simulation Output" being an input shows how scenario results feed back into the holistic model.

### **9. Advanced GNN-based Clustering Analysis**

* **What the User Sees:**
  + **Page Title:** "Advanced Analysis: GNN-Powered Insights for [Selected District/Scenario]"
  + **Section 1: Analysis Configuration:**
    - [Dropdown: Select Data Source for Analysis] (Options: "Baseline: Northwood District (2025)", "Scenario: High Ambition 2050 (Year: 2035)", "Scenario: High Ambition 2050 (Year: 2050)") - This allows analyzing different states of the district.
    - [Dropdown: Select GNN Analysis Type / Goal]
      * "Identify Potential Energy Communities (Load Complementarity)"
      * "Group Buildings for Targeted Retrofit Campaigns (Physical & Energy Similarity)"
      * "Pinpoint Grid Congestion Contributors (Network Stress Propagation)"
      * "Assess DER Suitability Zones (e.g., best areas for community solar based on grid capacity & local demand)"
    - [Dropdown: GNN Model Architecture (Advanced)] (Options: "GraphSAGE (Default)", "GCN", "GAT" - with tooltips explaining briefly). Hidden for non-expert roles.
    - [Button: Run GNN Analysis] (Shows progress bar/spinner during execution).
  + **Section 2: GNN Analysis Results (Dynamic, updates after run):**
    - **Subsection 2.1: Map Visualization:**
      * Interactive map of the district. Visualization depends on Analysis Type:
        + **Energy Communities:** Buildings color-coded by cluster ID. Legend shows Cluster 1 (Blue), Cluster 2 (Green), etc. Tooltip on building: "ID: NB-0112, Belongs to: Energy Community Alpha".
        + **Retrofit Candidates:** Buildings color-coded by retrofit priority group (e.g., Red=High Priority, Yellow=Medium, Green=Low). Tooltip: "ID: NB-0753, Retrofit Group: High (Old construction, high demand)".
        + **Grid Congestion Contributors:** Transformers and Feeders color-coded by their GNN-calculated "Influence Score" on congestion (e.g., Dark Red = High Influence). Buildings might be highlighted if they are primary drivers.
        + **DER Suitability Zones:** Areas on map shaded by suitability score (e.g., Dark Green = Highly Suitable for Solar).
    - **Subsection 2.2: Cluster/Group Details (Table or Cards, context-dependent):**
      * **For Energy Communities:**
        + Card per Cluster: "Community Alpha (15 Bldgs)". Key characteristics: "High Residential Load, Medium PV Potential". Aggregated load profile chart for this cluster. [Link: View Member List]
      * **For Retrofit Candidates:**
        + Table: Group ID, No. of Buildings, Avg. Age, Avg. Demand, Common Issues (e.g., "Poor Insulation").
    - **Subsection 2.3: Key Insights & Recommendations (Text Area - Potentially AI-Generated Summary):**
      * Example for Energy Communities: "GNN identified 4 potential energy communities. Community Alpha (15 buildings, primarily residential) shows strong potential for shared battery storage due to complementary morning/evening peaks. Consider a 100kWh battery in this zone."
      * Example for Grid Congestion: "Transformer T-03 and connected Feeder F-05B are identified as critical contributors to potential overloads under high EV adoption. Reinforcement or targeted demand response in this zone is recommended."
    - **Subsection 2.4: GNN Model Performance (Advanced - for experts):**
      * "Accuracy/Silhouette Score (for clustering): 0.75"
      * "Key Features Influencing Results: Building Type, Demand Profile Shape, Proximity to Substation."
* **Buttons & Interactive Elements (Post-Analysis):**
  + [Button: Export Cluster/Group Assignments (CSV)]
  + [Button: Export GNN Insights (PDF Summary)]
  + [Button: Use Identified Group for Intervention Scenario] (e.g., selects buildings in "Retrofit Group: High" and takes user to Section 5 to apply a retrofit package).
  + [Button: Re-run with Different Parameters]
* **Happenings (User Interactions):**
  + User selects "Scenario: High Ambition 2050 (Year: 2035)" as data source.
  + User selects "Identify Potential Energy Communities" as analysis type. Clicks Run GNN Analysis.
  + After processing, the map shows colored clusters. The details panel lists the communities and their characteristics. The insights panel suggests actions.
  + User clicks "Use Identified Group for Intervention Scenario" for "Community Alpha," which might pre-select these buildings in the Intervention Definition screen.

### **10. Reinforcement Learning (RL) Strategic Planning**

* **Page Title:** "Automated Strategic Planning via Deep Reinforcement Learning"
* **Conceptual Overview:** This page allows users to set up and run an RL agent that interacts with the digital twin (as its environment) to find an optimal long-term plan.
* **Section 1: RL Configuration & Goal Definition:**
  + [Dropdown: Select Baseline District State] (e.g., "Northwood District - Current State 2025")
  + [Dropdown: Select Scenario Context (Optional)] (e.g., "High Ambition 2050 Feasibility Constraints & Targets"). If selected, RL will try to operate within these bounds.
  + **RL Agent's Mission (Define Reward Function Components via Sliders/Weights):**
    - Title: "Define What 'Optimal' Means for the AI Agent:"
    - [Slider] Minimize Total System Costs (CAPEX & OPEX over 2025-2050): Weight: [80%] (Tooltip: "Agent will be rewarded for cost-effective solutions.")
    - [Slider] Minimize Cumulative CO2 Emissions (2025-2050): Weight: [90%] (Tooltip: "Agent rewarded for decarbonization.")
    - [Slider] Maximize Grid Reliability (Minimize Violations & Outages): Weight: [70%] (Tooltip: "Agent penalized for actions causing grid stress.")
    - [Slider] Maximize Renewable Energy Utilization: Weight: [60%]
    - [Slider] Adherence to Policy Targets (from Scenario Context): Weight: [50%] (Tooltip: "Agent rewarded for meeting predefined targets like CO2 reduction %.")
  + **RL Action Space (What the Agent Can Do - Informational, with some high-level toggles):**
    - "Agent can propose: Building Retrofits (Yes/No), Solar PV (Yes/No), Batteries (Yes/No), EV Chargers (Yes/No), Grid Upgrades (Yes/No)." (These are usually all 'Yes').
    - "Max Investment per Action/Year (€): [Input field, e.g., 200,000]" (Agent's individual decision budget).
  + **RL Environment Settings (Advanced):**
    - "Planning Horizon for RL: 2025 to [2050]" (from scenario or default)
    - "Number of Training Episodes: [Input, e.g., 10,000]" (Tooltip: "More episodes = better learning, but longer training.")
    - [Dropdown: RL Algorithm] ("PPO (Default)", "SAC")
* **Section 2: RL Training & Monitoring ("AI Thinking" Visualization):**
  + [Button: Start RL Strategic Planning Agent]
  + **During Training (Progress View):**
    - **Headline:** "RL Agent Training: Episode [1234 / 10000]"
    - **Sub-section: Agent Learning Progress**
      * **Chart 1 (Live): Average Reward per Episode (Line chart):** Shows overall learning trend (should generally increase). X-axis: Episode #. Y-axis: Avg. Reward Score.
      * **Text:** "Estimated Time Remaining: [hh:mm:ss]"
    - **Sub-section: Current Best Strategy Preview (Updates periodically, e.g., every 100 episodes)**
      * **Title:** "Snapshot: AI's Current Best Strategy (Episode 1200)"
      * **Key KPIs (Text):** Est. Total Cost: €X.XM, Est. CO2 Emissions: Y,YYY tonnes, Grid Violations: Z
      * **Simplified Timeline Preview (Text list or mini-timeline graphic):**
        + "2027: Retrofit Building Group Alpha (-10% demand)"
        + "2030: Install 500kW Solar PV on Commercial Zone C"
        + "2035: Deploy 200kWh Battery at Substation North"
        + "..."
      * (Optional: A very abstract animation or graphic depicting "exploration" - e.g., a network graph with nodes lighting up as agent explores states/actions).
    - [Button: Pause Training], [Button: Stop Training & View Best Plan So Far]
* **Section 3: RL-Generated Optimal Roadmaps (View after training or loading results):**
  + **Page Sub-Title:** "AI-Optimized Strategic Roadmaps"
  + **Top 3 AI-Generated Roadmaps (Presented as Cards):**
    - **Card 1: Roadmap A (e.g., "Balanced Approach")**
      * Summary KPIs: Cost: €9.5M, CO2: 3.5k t, Reliability: High
      * [Button: View Detailed Roadmap A]
    - **Card 2: Roadmap B (e.g., "Aggressive CO2 Reduction")**
      * Summary KPIs: Cost: €11M, CO2: 2.8k t, Reliability: Medium
      * [Button: View Detailed Roadmap B]
    - **Card 3: Roadmap C (e.g., "Cost Optimized")**
      * Summary KPIs: Cost: €8M, CO2: 4.5k t, Reliability: Medium
      * [Button: View Detailed Roadmap C]
  + **Detailed Roadmap View (Loads when a "View Detailed Roadmap" button is clicked - replaces the Top 3 cards view or opens in a larger section):**
    - **Selected Roadmap Title:** "Detailed View: AI Roadmap A (Balanced Approach)"
    - **Animated Timeline Visualization:**
      * Horizontal axis: Years (e.g., 2025, ..., 2050). [Button: Play Animation >] (animates year by year).
      * Vertical tracks for intervention types. Interventions appear on the timeline with a subtle animation as the "Play" progresses or when initially loaded.
      * **Fake Data on Timeline:** Similar to before, showing specific actions in specific years.
    - **Roadmap Table/Chart (Detailed breakdown):**
      * Columns: Year, Action/Intervention, Target Area/Asset (e.g., "Building Cluster X", "Transformer T-02", "All South-Facing Roofs"), Details (e.g., "Deep Retrofit", "Capacity +50%"), Est. Impact (CO₂, cost, overloads for that year/action), Mini-Map Icon (conceptual: shows a small map thumbnail of target area).
      * **Fake Data Rows:**
        + 2027, "Retrofit", "Res. Cluster Alpha", "Deep Energy", "-5% CO2 (Dist.), €200k, 0 new overloads", [Map Icon]
        + 2029, "Solar PV", "Comm. Zone C Roofs", "500 kWp", "+10% Renewables, €150k", [Map Icon]
        + 2032, "Battery", "Substation North", "250kWh", "-1 Grid Overload, €100k", [Map Icon]
    - **KPI Dashboard for this specific RL Plan:** (Same as before, comparing to baseline).
    - **Map View:** Showing final state of district according to this selected RL plan.
    - **"Agent's Rationale" (Conceptual):** (Same as before).
* **Buttons & Interactive Elements (for Detailed Roadmap View):**
  + [Button: View Detailed Annual Intervention Log]
  + [Button: Compare This RL Plan with Other Scenarios] (Navigates to Section 11).
  + [Button: Export This RL Roadmap & Rationale (PDF)]
  + [Button: Back to Top 3 RL Roadmaps]
  + [Button: Re-run RL with Adjusted Rewards/Constraints]
* **Happenings (User Interactions):**
  + User sets up reward weights, starts RL agent. Monitors training via live charts and scenario previews.
  + After training, views the Top 3 roadmaps. Clicks "View Detailed Roadmap A."
  + Explores the animated timeline and detailed table for Roadmap A.
  + Compares Roadmap A with a manual scenario.

### **11. Scenario Comparison & Decision Dashboard**

(No changes from previous detailed version. This page will be used to compare manual scenarios against the AI-generated roadmaps selected from Section 10).

### **12. Export Reports & Recommendations**

* **What the User Sees:** (Largely same as before)
  + **Report Configuration Panel:**
    - [Dropdown: Select Scenario/Roadmap for Report] (Options now include saved manual scenarios and the AI-Generated Roadmaps, e.g., "RL Roadmap A (Balanced)", "Current Scenario Comparison View").
    - Other fields (Title, Prepared by, Sections to Include, Custom Notes, Export Format) remain the same.
    - If an RL Roadmap is selected, "Sections to Include" might have specific options like "AI Agent Configuration," "RL Training Summary," "Detailed AI Roadmap Timeline & Table."
* **Buttons & Interactive Elements:** (Same as before)
* **Happenings (User Interactions):** (Same as before, but user can now select an AI-generated roadmap to report on).

### **13. Stakeholder Feedback & Platform Iteration (New Section)**

* **Page Title:** "Feedback & Platform Improvement"
* **Conceptual Overview:** A dedicated space for users to provide structured feedback on the platform's usability, the generated plans, and suggest improvements. This is not for iterative *scenario* planning (that's done by going back to earlier steps), but for feedback on the *tool itself*.
* **What the User Sees:**
  + **Section 1: General Platform Feedback:**
    - **Headline:** "Help Us Improve the Energy District Planner AI!"
    - [Rating Scale: Overall Platform Usability (1-5 stars)]
    - [Text Area: What do you like most about the platform?] (Placeholder: "e.g., The interactive map views, the scenario comparison...")
    - [Text Area: What could be improved or is missing?] (Placeholder: "e.g., More detailed grid component models, faster simulation times for X...")
    - [Text Area: Were there any parts of the platform that were confusing or difficult to use?]
  + **Section 2: Feedback on a Specific Scenario/Roadmap (Optional):**
    - [Dropdown: Select a Scenario/Roadmap to provide feedback on] (Lists all saved scenarios and AI roadmaps).
    - If a scenario/roadmap is selected:
      * [Rating Scale: Clarity of this Plan's Results (1-5 stars)]
      * [Rating Scale: Trustworthiness/Plausibility of this Plan (1-5 stars)]
      * [Text Area: Specific comments or concerns about this Plan/Roadmap]
  + **Section 3: Feature Requests:**
    - [Text Area: Do you have any requests for new features or analyses?]
  + **Section 4: Bug Report (Optional):**
    - [Text Input: Brief description of the issue]
    - [Dropdown: Which page/module did this occur in?]
    - [Text Area: Steps to reproduce the issue (if possible)]
* **Buttons & Interactive Elements:**
  + All form elements (rating scales, text areas, dropdowns).
  + [Button: Submit Feedback]
  + [Link: Contact Support for Urgent Issues]
* **Happenings (User Interactions):**
  + A Grid Operator user might rate the platform 4 stars, praise the RL planning module, but suggest improvements to the detail level in the grid asset tables.
  + A Policy Maker might provide feedback on an AI-generated roadmap, questioning the feasibility of a specific intervention suggested by the AI.
  + Clicking Submit Feedback sends the form data to a backend for collection (e.g., to a database or email). A confirmation message appears: "Thank you for your feedback!"

This more detailed guide should give your UI designer a much stronger starting point, enabling them to create meaningful and visually representative mockups for each stage of the platform.