From Wastes to Energy Stability: The *GridApp* Perspective

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Purpose and Scope of *GridApp*

The recent blackout in Spain and Portugal has once again highlighted that our power grids may not be adequately prepared for the demands of the ongoing energy transition — a transition that requires careful, forward-looking planning. Yet, many of the tools available for such planning are either prohibitively expensive or have steep learning curves.

To address these gaps, the Energy Modelling team at the RSERC of TII has developed *GridApp*, a platform designed to explore and analyze a wide range of energy challenges, capable of:

- Intuitive and accessible energy mix and grid simulations, which can take requests in natural language and produce a detailed, accessible report.
- Planning renewable energy installations and novel energy farms, integrating storage systems and electrifying transport.
- Providing strategic insights into optimal energy mixes to support a successful low carbon energy transition and meet the national environmental goals.

Through realistic scenario modelling, *GridApp* offers practical recommendations to policy makers in the UAE and throughout the Gulf region, but it may also incorporate other geographic areas.

This first episode of our "What if" series, focuses on the effects of converting waste to grid scale biomass energy — demonstrating how *GridApp* makes complex analyses accessible, helping the user to align energy strategies with environmental objectives.

The Waste Problem

The United Arab Emirates (UAE) produces large volumes of waste, including municipal solid waste (MSW), organic waste, construction and demolition debris, and other refuse. The rapid growth of this waste stream presents significant management challenges nationwide. While a considerable portion of construction waste is successfully recycled, much of the remaining waste ends up in landfills, leading to emissions of methane, a greenhouse gas 28 times more potent than CO_2.

To combat this, some Emirates are now adopting technologies like Refuse Derived Fuel (RDF) to valorize organic and biomass waste by generating sustainable energy, thus helping the UAE's 2030 emissions commitments and the shift to a low-carbon economy. Solar energy is currently the dominant renewable source in the UAE, but its variability could in some circumstances lead to grid instability. In this context, bioenergy stands out as a complementary, stable and reliable baseload power that can supply reliable 'on-demand' generation from several sources, including organic waste and MSW.

We wanted to investigate how much contribution Waste to Energy could make, so using one of *GridApp* most important features, we present here an analysis of the optimal resource allocation and cost optimization, while prioritizing grid stability and emission management.

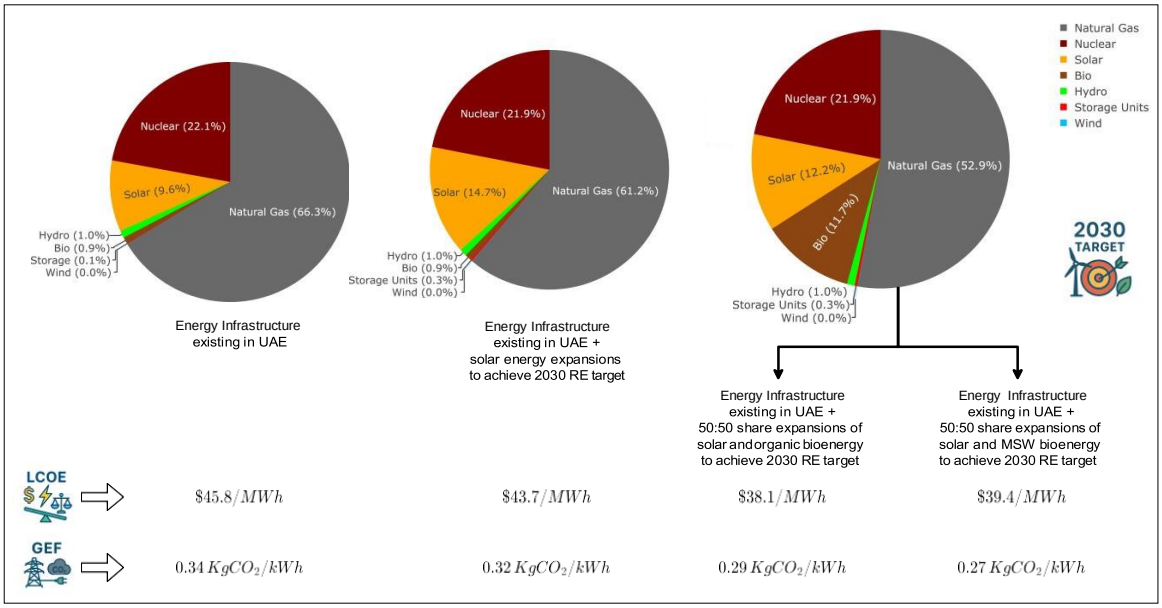

Figure 1: Energy mix for different scenarios, with Levelized Cost of Electricity (LCOE), grid emission factor (GEF) progressing towards decarbonization targets

Using `GridApp` to Identify Low-Emission, Cost-Effective Generation Mixes

Currently, the UAE's grid emission factor remains high due to a low share of renewable energy sources, made of solar and bioenergy, each contributing to the overall energy mix by 9.6% and 0.9% respectively (the breakdown of electricity generation sources for all scenarios is illustrated in Figure 1). However, the UAE strategy targets that the emission factor needs to decrease significantly by 2030. To support this transition, the UAE has already planned to triple its renewable energy capacity to 14.2 GW by 2030 [1]. Using open-access data on the UAE's grid infrastructure and current energy production, we conducted simulations to identify the most cost-effective and environmentally friendly electricity generation pathways. These simulations aim at minimizing the Levelized Cost of Electricity (LCOE) while achieving a grid emission factor aligned with the national climate targets. In the analysis we evaluate the four scenarios listed in Table I.

Scenario 1 - the baseline scenario - represents the current state of electricity generation in the UAE. In this baseline simulation using *GridApp*, we estimate a Levelized Cost of Electricity (LCOE) of $45.8/MWh and a grid emission factor of 0.34 Kg CO_2/kWh.

In Scenario 2, we model the impact of tripling the renewable energy target solely through solar power expansion. While this marks a significant step forward, the resulting grid emission factor reaches 0.32 Kg CO_2/kWh, falling short of the emissions reduction target. Also, as hinted above, greater stability may be achieved using a more varied renewable energy strategy.

Scenario	Annualized Fuel cost (Billion $)	LCOE ($/kWh)	Grid emission factor (kg CO_2/kWh)	Clean energy share (%)
1. Baseline scenario	9.89	45.8	0.34	36.5
2. Solar capacity expansion	9.2	43.7	0.32	40
3. Solar and organic bioenergy capacity expansion	8.65	38.1	0.28	46.5
4. Solar and MSW bioenergy capacity expansion	8.65	39.4	0.29	46.5

Table 1: Evaluation of Solar and Bioenergy Scenarios: Economic and Emission-Related Indicators [5].

To explore more effective solutions, we modelled an alternative: what if the planned tripled renewable

capacity came from a combination of solar and biomass. These are 'what if' scenarios 3 and 4. In each, biomass is sourced from organic waste or municipal solid waste. To achieve renewable energy target we examined a range of solar-to-bioenergy ratios between the two extremes 100% solar and 100% bioenergy. A nearly 50:50 mix emerged as the most balanced and effective option. Table 1 shows the comparative analysis of all four scenarios in terms of economic, environmental, and clean energy outcomes. However, these energy amounts require an adequate mass of waste and obtaining this may represent a key challenge of the biomass technique.

Do We Have Enough Waste for This?

Abu Dhabi's waste management company facility (by Tadweer) is designed to process 900,000 tons of waste, annually generating up to 80 MW of electricity [3]. At this scale, achieving the 2030 renewable energy target using waste-to-energy alone would require approximately 63 million tons of waste per year! As a comparison, WtE's plant at Sharjah, can process 30,000 tons, outputting 30 MW [2]). As a sanity check, in 2023, the UAE generated only around 4.7 million tons of municipal solid waste and 3.7 million tons of other organic waste [4]. This could feed about 746 MW capacity, meaning that under the current conditions, we are limited to 13.2% of planned renewable expansion from waste. Table 2 compares the four scenarios in terms of economic, environmental, and clean energy outcomes.

Table 2: Evaluation of Solar (90%) and Bioenergy (10%) Scenarios: Economic and Emission-Related Indicators [5]

Scenario	Annualized Fuel Cost (Billion $)	LCOE ($/kWh)	Grid Emission Factor (kg CO_2/kWh)	Clean Energy Share (%)
Baseline scenario	9.89	45.8	0.34	36.5
Solar capacity expansion	9.2	43.7	0.32	39.5
Solar and organic bioenergy capacity expansion	9.1	43	0.31	40
Solar and MSW bioenergy capacity expansion	9.8	43.2	0.32	40

The analysis above illustrates how modelling tools like our *GridApp* can function at best when accompanied by adequate data and realistic assumptions. It would be very desirable to use Biomass to the extent needed (approx. 50% ratio between solar and biomass) and get the desired carbon index, but Table II shows that the best achievable value under present conditions (i.e. limited to the waste available) is only 0.31 Kg CO_2/kWh - Appealing, but insufficient.

Obviously, an improvement of the waste to energy conversion rate, by the introduction of novel technologies, would make this scenario more attractive. But even if waste-to-energy alone cannot fulfill the entire renewable target, it still can significantly contribute towards a steady, low-emission power supply, helping the reduction of the dependence on natural gas and supporting grid stability. All this, of course, does not take account of the benefits of diverting substantial amounts of waste from landfills, which if valued correctly, may make the decision of regulators and planners more inclined to support further waste to energy plants.

Biomass can further supplement the feedstock for this waste to energy power plants, particularly through the cultivation of salt-tolerant crops such as Salicornia. These 2nd generation biomass crops grow using saline or brackish water, minimizing direct competition with plants that use precious land and freshwater resources. Cultivating them on marginal lands could support energy production while conserving fertile land and water, ultimately aiding in meeting grid emission reduction targets and promoting environmental sustainability.

Revisiting `GridApp`: Expanding Capabilities – Future Directions

GridApp modularity permits users to construct and store multiple regional scenarios into a portfolio, to be examined and compared all at once and easily modified by a non-technical user. This feature is essential for long-term strategic decision-making in both national and transnational energy planning. And thanks to its large language model (LLM)-driven interface, *GridApp* user questions are interpreted in natural language and automatically translated into relevant scenarios. Our platform places powerful AI tools directly at the user's fingertips, turning complex analyses into swift, interactive explorations.

The example above showed an optimized solar and bioenergy mix and its impact on the grid emission factor. While improving the decarbonization targets over the status quo, this is only one of the viable solutions: an emerging paradigm in energy systems planning that *GridApp* can tackle is the integration of electric vehicles (EVs) as distributed energy storage units.

In the next episode of the series dedicated to our *GridApp*, we will explore how EVs may participate in the grid stabilization, turning from mere energy consumers to grid energy suppliers. This vehicle-to-grid (V2G) approach, once considered speculative, is gaining traction across energy research and deployment communities.

We welcome your comments, suggestions, and collaborations as we continue developing *GridApp* to support a cleaner, smarter, and more resilient energy future.

References

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