Solution Showcase

Boosting the Performance of Industrial Equipment With Simulation

CPFD brings GPU-accelerated models to computational fluid dynamics.

> "We have been honored to receive several high commendations and awards in recent years, including Best Software Technology from Hydrocarbon Processing. This success has in large part been enabled by using a parallelized code built on the NVIDIA® CUDA® technology stack"
>
> **Peter Blaser**, Vice President of Operations, CPFD Software

Fluidized catalytic cracking units (FCCU) are at the heart of modern refineries, processing a wide variety of feedstocks into fuels and chemicals.

While FCCUs are used extensively in traditional refineries, similar processes are increasingly being used in new applications for renewable energy, decarbonization, and sustainability innovations.

These industrial units often operate 24/7 for years on end, making reliability and performance crucial. With lost production, the cost of unplanned FCCU shutdowns can be upwards of $1M per day.

With limited data and testing capabilities, even planned turnaround changes can degrade baseline performance or fail to address the root causes of underperformance.

To maintain service standards and protect FCCU economics, it's key to develop "first-time-fix" capabilities while minimizing the risk associated with changes.

Introducing CPFD's Barracuda Virtual Reactor

CPFD Software is a technology company in the field of computational fluid dynamics. Their team of engineers focuses on advancing multiphase simulation for fluidized bed reactors and other fluid-particle systems used in refining, petrochemicals, cement manufacturing, power generation, and other energy-intensive industries.

CPFD makes simulation software in the field of computational fluid dynamics (CFD) to help refiners and energy industry technology developers predict fluid, particulate-solid, thermal, and chemically reacting behaviors.

Industry

- Oil & Gas

Challenges

- Identifying root causes of underperformance
- Implementing untested FCCU changes
- Optimizing FCCU design and processes

Benefits

- Reduce risk of changes
- Extend run length
- Minimize unexpected shutdowns
- Cost savings with optimized production

PREFERRED PARTNER

With CPFD's physics-based software package, **Barracuda Virtual Reactor**, customers can model hydrodynamics, thermal behavior, and chemical reactions in FCCUs and other industrial units.

These simulations help reduce the risk associated with design, scale-up, commercialization, and troubleshooting industrial processes. Barracuda simulations also help to:

- Determine the root cause of underperformance
- Reduce turnaround risk through virtual testing
- Enable rapid, informed technology development and scale-up
- Maintain operational readiness through digital assets

Refiners use CPFD's award-winning Barracuda Virtual Reactor software to address FCCU-specific issues such as afterburn, emissions, catalyst losses, erosion and reliability, catalyst circulation stability, gas and catalyst maldistribution, pressure balance issues, feed distribution, riser performance, throughput limitations, and the effects of co-processing renewable feedstocks.

To run simulations containing trillions or more particles in a business-relevant time scale, CPFD has parallelized its models using NVIDIA GPU technology.

Viva Energy Australia Recaptures RCCU Performance Levels

Viva Energy's Geelong Refinery in Victoria, Australia, processes 120,000 barrels per day (bpd) of crude oil and supplies 50 percent of Victoria's and 10 percent of Australia's fuel demand.

In 2011, following hardware changes to the refinery's 40,000-bpd residue catalytic cracker unit (RCCU), the unit suffered increased afterburn and reduced throughput. Sudden flue gas temperature spikes required regular panel operator intervention and forced the refiner to reduce rates by 10 percent for certain feedstocks, costing tens of thousands of dollars per day.

Despite the advanced analytics techniques used by refinery engineers, the dynamic afterburn effects showed no correlation with any measured process conditions.

Ahead of a 2016 turnaround, the Geelong plant opted to use Barracuda Virtual Reactor to run simulations to:

- Understand the root cause of underperformance
- Perform virtual testing of intended hardware changes
- Minimize the risk of unintended adverse effects
- Identify opportunities for further optimization

GPU Speedup Results

- 50–500X speedups
- Week-long simulations in an hour
- Previously intractable problems now solvable

FCCU Results

- 75 percent reduction in panel interventions
- 4 percent higher daily average throughput
- 5°C lower average afterburn

NVIDIA Products Used

- NVIDIA DGX™ systems

NVIDIA Software Used

- NVIDIA CUDA
- NVIDIA CUDA-X™

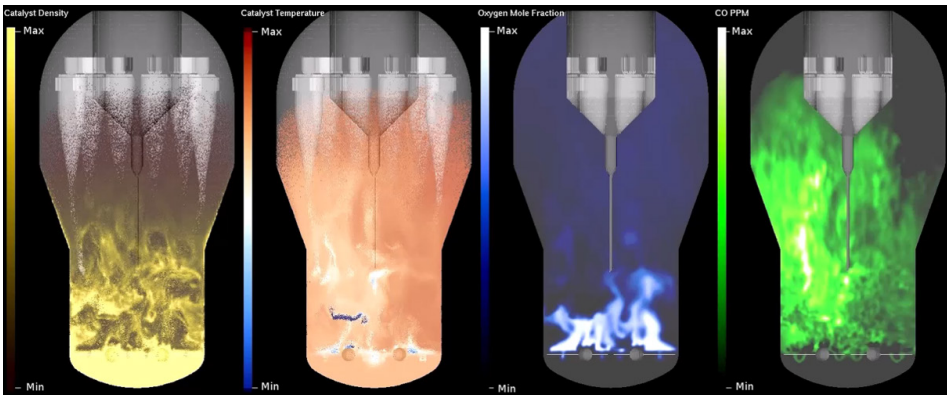

Figure 1. From left to right, this Barracuda Virtual Reactor simulation shows catalyst density, catalyst temperature, oxygen mole fraction, and carbon monoxide concentration in parts per million.

After comparing Barracuda's pre-2011 and post-2011 simulations, engineers concluded that 2011 turnaround changes introduced more maldistribution of air and catalyst in the regenerator, resulting in the observed temperature spikes. The models also indicated that the most likely source of the maldistribution was the spent catalyst inlet device (SCID).

The model was then applied to simulations for the proposed 2016 turnaround changes. The simulation showed that the proposed changes, including reverting the SCID to the pre-2011 configuration and optimizing the air grid nozzles, would reduce the gas maldistribution entering the cyclones and correct underperformance.

The model was proven correct by twelve months of data collected immediately before and after the 2016 turnaround. Performance rebounded, with observed improvements of:

- 5°C lower average afterburn
- 75 percent reduction in panel operator interventions
- 4 percent higher daily average throughput

> "This project delivered an excellent outcome, giving us confidence that specific hardware changes would restore the operation of our cracker to the level we expect—which it did. Our team's collaborative approach brought together CPFD's expertise and our refinery knowledge."
>
> **Thys Heyns**, General Manager of Refining, Viva Energy Australia

GPU-Accelerated Modeling for FCCU Reactors in the Cloud

Barracuda Virtual Reactor users have access to high-performance computing through **Microsoft Azure virtual machines** powered by NVIDIA A100 Tensor Core GPUs.

With Barracuda available on Azure cloud, CPFD customers can test models and see results without the overhead cost of purchasing and maintaining their own on-premises hardware.

With a speedup of **150–200X** compared to CPU, users can complete week-long simulations in an hour or conduct 150–200 simulations per week.

On top of these results, benchmarking is underway using newer Microsoft Azure systems that demonstrate more than 500X speedups for larger simulations.

The chart below shows sample GPU and multi-GPU speedups. Four different cases with different model sizes were tested, case 1 being the smallest and case 4 the largest. All cases show additional speedup when utilizing two GPUs compared with one GPU.

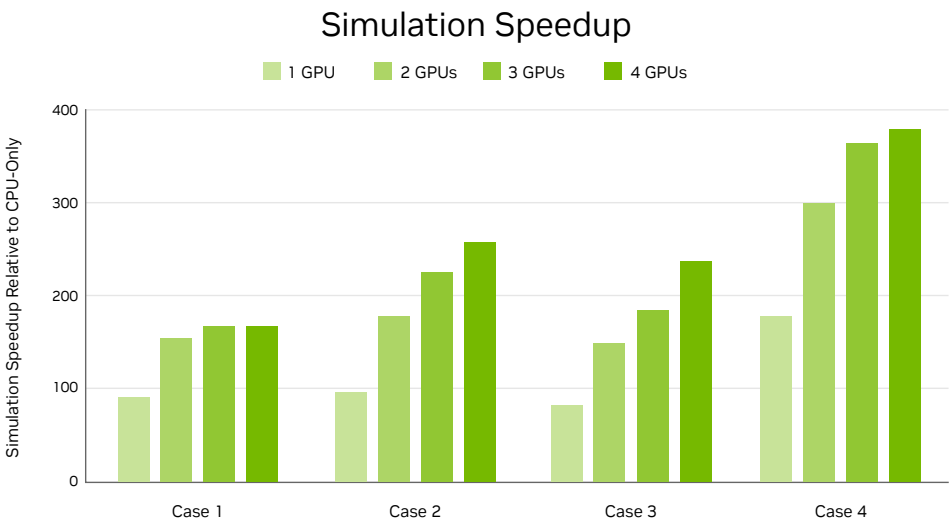

Figure 2. Simulation speedup is relative to CPU-only speed on an NVIDIA DGX Station A100 using one, two, three, and four GPUs in multi-GPU mode. All cases represent industrial-scale fluidized beds. Case 1 is the coarsest model tested using approximately 250,000 cells and 30 million computational particles. Case 4 is the largest with about 1 million cells and 55 million computational particles.

> "The observed speedups of over 200X, combined with the convenience of the Azure platform, provide our clients with virtually unlimited, on-demand compute bandwidth as they tackle some of our planet's toughest engineering, energy, and sustainability challenges."
>
> **Peter Blaser**, Vice President of Operations, CPFD Software

GPU Parallelization Powered by NVIDIA

By leveraging NVIDIA's CUDA framework and GPU systems, Barracuda Virtual Reactor software is able to simulate large-scale, industrial-sized units efficiently. Their multiphase particle-in-cell (MP-PIC) implementation has accelerated the flow solver, chemical reactions, and key particle operations with GPUs—processes which would be impractical to run on CPUs alone.

In 2021, CPFD added multi-GPU parallelization capabilities to their offering, enabling Barracuda Virtual Reactor to efficiently scale and run on NVIDIA DGX hardware systems. Users can now run simulations on up to eight NVIDIA A100 Tensor Core GPUs in a **DGX system** or four GPUs in a workstation that fits under a desk. Running on a four-GPU workstation, simulations were completed 400X faster compared to a CPU-powered workstation.

For large-scale operations with massive datasets, Barracuda Virtual Reactor can run on NVIDIA HGX™ A100 GPUs, hardware specifically designed to handle simulation, data analytics, and AI workloads.

CPFD continues to take advantage of NVIDIA's latest technology releases. New benchmark results show Barracuda Virtual Reactor simulations experience a further 25 percent speedup running on NVIDIA H100 Tensor Core GPUs compared with the previous A100 generation.

To demonstrate the power of GPU speedups, CPFD revisited a 2012 simulation modeling 400,000 cells running on CPUs. The model would have taken three years to complete and was never finished. Today, a comparable model running on NVIDIA DGX systems can be completed in 13 hours.

In addition to exponentially faster model completion, GPU speedups bring the possibility of running larger domain models—models with finer spatial resolution, more detailed physics, and more complex chemical reactions. These additional insights into system dynamics can inform FCCU design and operational decisions.

With such advanced simulations at their fingertips, operators can improve FCCU reliability and performance to previously unattainable standards. These improvements have a positive impact on refinery economics, uptime, customer satisfaction, and overall competitive advantage.

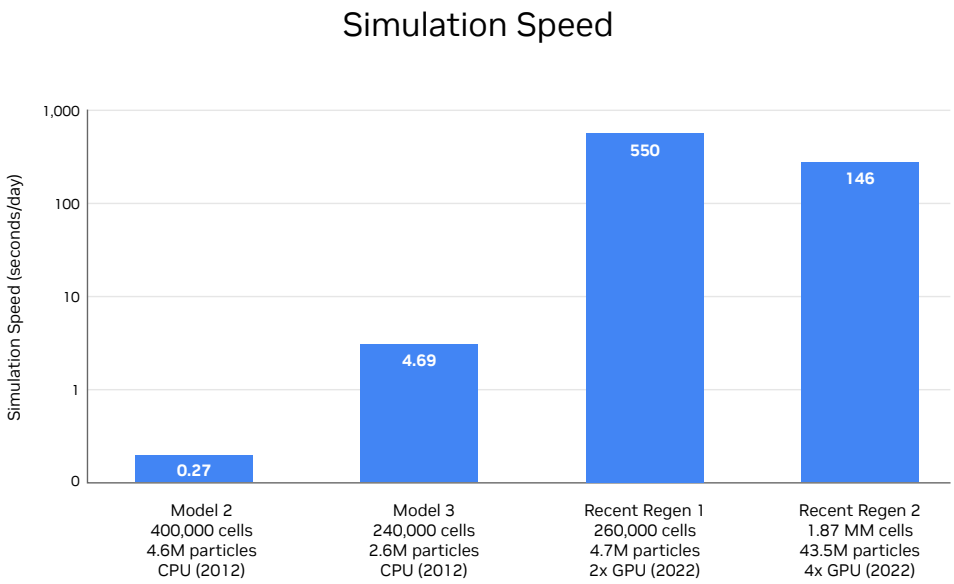

Figure 3. CPFD has used GPU speedups to complete large models in business-relevant timelines. Models 2 and 3 were taken from an FCC regenerator simulation study, first created in 2012. Model 2 consisted of 400,000 cells and 4.6 million computational particles and would have taken approximately three years to complete using hardware and software technology available at that time. As a result, model 3 was created, which consisted of 240,000 cells and 2.6 million computational particles, with 2012 results available in about two months. Recent Regen cases 1 and 2 were similar models run in 2022 using two NVIDIA A100 GPUs, with results obtained in 13 hours and two days, respectively.

CFPD's Barracuda Virtual Reactor—Powered by NVIDIA

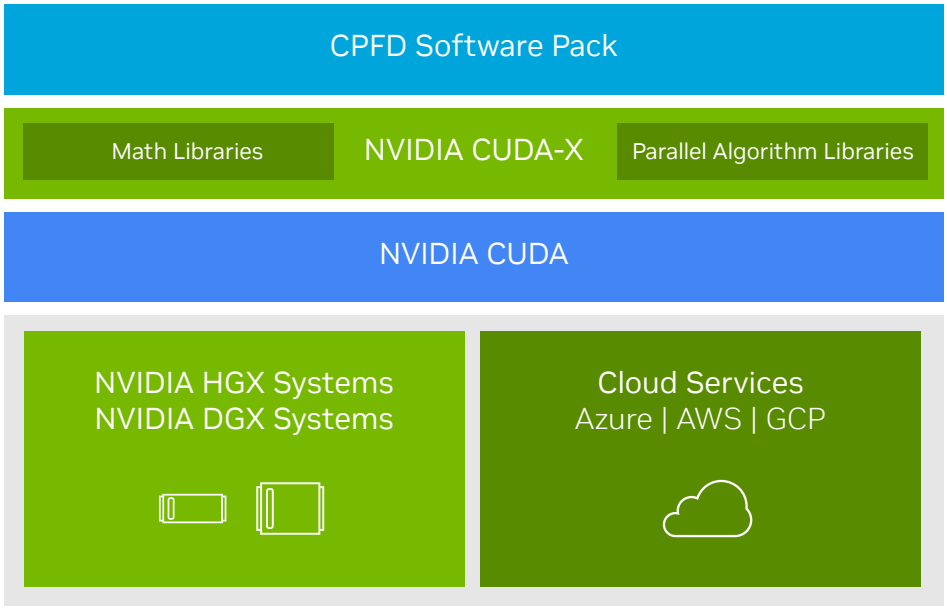

Figure 4. CPFD uses a parallelized code built on NVIDIA technology.

Ready to Get Started?

To learn more about CPFD Software, visit:
cpfd-software.com/applications/fccu

Learn how NVIDIA DGX systems are delivering AI-powered insights, visit: **www.nvidia.com/dgx**