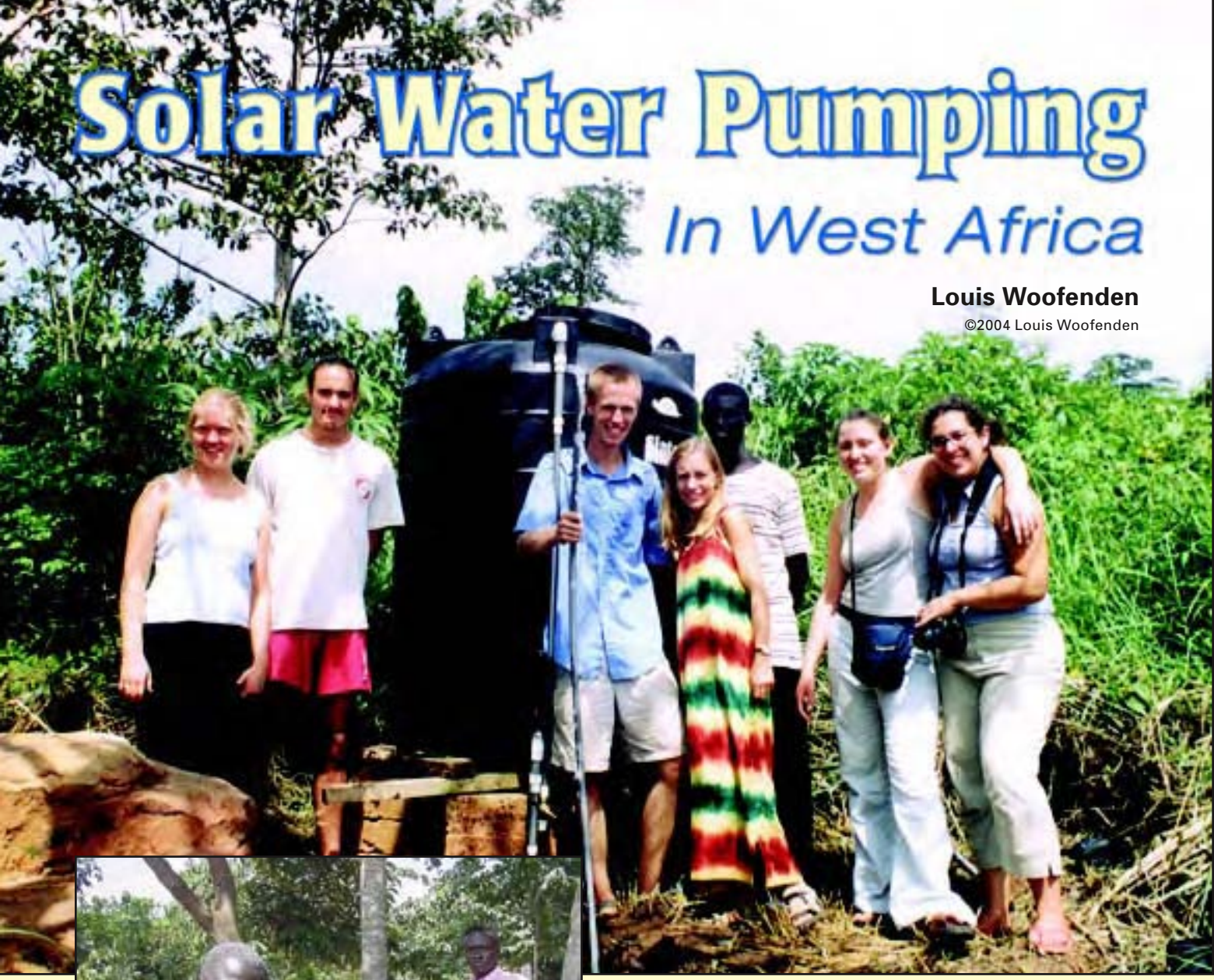
Solar Water Pumping
In West Africa

Louis Woofenden



The Ghanaian schoolchildren gathered excitedly around as Reverend Gyamfi got ready to open the water spigot. It was only minutes since the water had started to flow from the holding tank into the pipes, so I wasn't sure if it would be at the spigot yet. But I had nothing to worry about. The water flowed out in a satisfying stream.

Above (L to R): Laura Gladish, Brian Smith, Louis Woofenden, Kelly Waddell, Kwame Adu, Rachel Gardam, and Sarah Walker were the main installation crew of a PV-powered water pumping system for the school in Asakraka, Ghana.

Left: Reverend Gyamfi uses the first water from the spigot to the delight of the schoolchildren.

I was so relieved—all the planning, preparation, and work had successfully come to completion. The staff and children at the school wouldn't need to walk down the hill to the well or return up the hill, trudging under the weight of full buckets. The New Church Preparatory School in Asakraka, Ghana, now had running water.

Students learn the fundamentals of solar electricity—the pump stops when a kid shades the PV panels.

Planning

The process had started months ago. Six Bryn Athyn College students (including me) had been planning a service internship since the fall of 2001. We'd be spending ten weeks in Ghana, West Africa, as interns in conjunction with our church's outreach office and the college we all attended. I'd heard from my older sister (who did a similar internship, and had also led a trip to Ghana over the summer of 2001) that the rural Asakraka school would love to have running water.

The school has three buildings, all with electricity, but the electrical supply was not entirely reliable, and expansion of their electrical system was not likely. All the water used for cooking, washing hands, and other tasks had to be hand-carried anywhere from 100 to 300 feet (30–90 m) up a steep hill. I started some research on what it would take to put together a solar-electric water pumping system to fill the school's needs.

With last-minute funding acquired from New Uses, a nonprofit church foundation, I spent much of my last two weeks before leaving for Ghana gathering the components for the system. Bob Maynard of Energy Outfitters, Inc. helped enormously. He made it possible to get everything together in time by quickly shipping two Sharp, 80 watt, solar-electric panels; a rack for the panels; and a Shurflo pump across the country. He also provided valuable advice about system components and other technical issues.

Kudos also to Direct Power and Water Corporation, whose staff took time out from other projects to build the rack for the panels. Thanks to this and other help, everything was ready and packed the day before we were scheduled to leave the U.S. When it came time to fly, Swiss Air was gentle with the panels and other equipment, and everything made it safely to Ghana.

African Arrival

Once we arrived in Ghana, my fellow interns and I worked at teaching, doing other projects, and simply acclimating to a new and wonderful culture. A few weeks later, we made a day trip up to Asakraka, a rural village near Volta Lake, the biggest man-made lake in the world. The trip was four slightly bumpy hours from the coastal city we were staying in through lush and beautiful jungle. During this short visit, I was able to take specific measurements and figure out how much pipe, wire, and other supplies we'd need for the water pumping system.

Over the next few weeks, I was able to buy wire and other electrical supplies in the electrical market in Ghana's capitol, Accra. I later went with Reverend Gyamfi (the minister and principal of the Asakraka church and school) to a commercial section of Accra where plumbing supplies are sold, and bought a polyurethane tank for water storage, some flexible tubing, and a few other needed supplies. Rev. Gyamfi had all the equipment trucked to Asakraka, where it awaited our arrival.

Arrival & Teaching in Asakraka

A week later, we arrived in Asakraka, and began work on the solar pumping system. We would have only eight days in Asakraka. In addition to the solar project, our group would be building a jungle gym for the schoolkids and organizing a library. We would all have to work hard to get everything done. Because of the time crunch, I'd need to cut back on teaching about solar electricity to the people there. Instead, I'd have to concentrate on simply getting the system up and running.

I did, however, have a chance to teach three different school "stages" (grades) about solar electricity. Using the two panels, I set the pump up as a small fountain in a bucket. The teachers were great—they took my simple explanations of how the panels and pump worked, and translated them into Twi, the local language.

The kids were very excited about the whole thing, and gathered around the bucket, pushing each other and jostling for position. We had to set up a perimeter of pieces of wood, just to protect the pump and panels. One of the most fascinating moments for the kids was when they shaded the panels and saw how the flow from the pump diminished. For a grand finale, I used the pump as a mister, and sprayed the kids all around. They had a blast. In fact, it soon turned into pandemonium, at which point we turned off the pump and went on to other parts of the project.

Locals and visitors work together to hoist and install the PV panels.

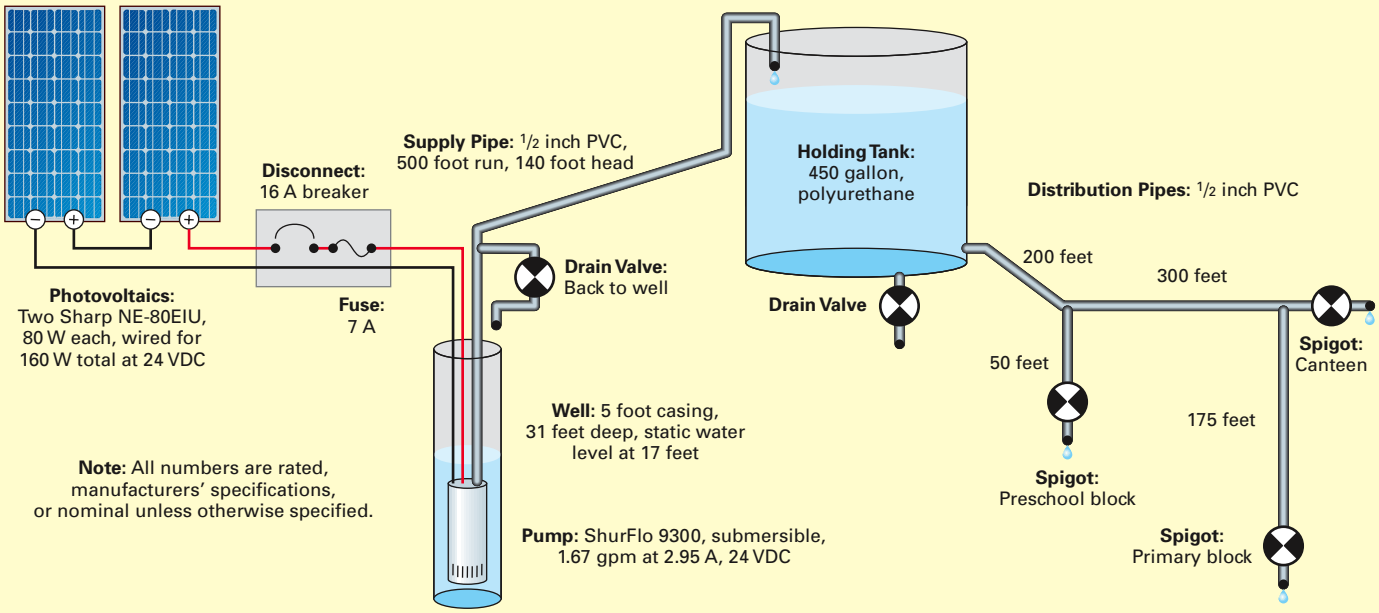
Mounting the panels on the DP&W rack—a 17 foot tall, 2 inch diameter steel pole supports the whole assembly.

Getting the Basics Done

The first order of business on the project was to look over everything. I then started working with Kwame, an active and enthusiastic church member and my main helper, to install the 185 foot (56 m) wire run. It would go from the top of one of the school buildings, where the panels would be mounted, to the wellhead, where the pump would be installed. Kwame, my five American companions, and I finished digging a 140 foot (46 m) long ditch.

The next couple of days were spent on the mostly mundane. We set the bottom of a 17 foot (5 m) tall, 2 inch diameter steel pole in concrete, and secured the pole to the school building's rafters. The rack for the panels would rest on the top of the pole. Kwame and I started running the wires through the conduit from the well to the panels.

I tried to glue all the pieces of conduit together first, and then run the wire through. This didn't work, because the conduit was undersized (by U.S. standards) for the job. In Ghana, they feed wire through each piece of conduit, and then glue them. So we broke the conduit run into a few sections and ran the wire. Kwame had fabricated new joints in the PVC, using a pointed tool and some hot coals. Then we glued it all back together. Ghanaian ingenuity triumphs—the Ghanaians can fix or do almost anything with very simple tools.



This completed the wire run from the pump site. We also made connections in an intermediary junction box. Kwame built a wooden box to hold a disconnect and fusing. It would be near the base of the pole that the panels would sit on.

By this time, I was a little worried. Although I would be able to get everything up and working, I thought I wouldn't have enough time to do the thorough education needed for Kwame and others to be able to maintain and troubleshoot the system. But there wasn't much I could do about it but keep on going. In fact, I was able to do a lot of teaching—mostly the hands-on type. I tried to get Kwame and other Ghanaians to do as much of the work as possible.

Whenever I or anyone else had spare time, there was always ditching to do! There was about 1,300 feet (396 m) of ditching, not even counting the ditch for the electrical conduit. The ditching included 500 feet (152 m) for the 1/2 inch water pipe that would run up to the water storage tank. From there, about 800 feet (244 m) of pipe would run to three different places where water was needed in the school—the school canteen (kitchen), the primary block, and the preschool block.

Concrete & Plumbing

By Friday night, halfway through our time in Asakraka, the project was in good shape. We'd been able to get a tremendous amount done in a single day, thanks to four Ghanaian workmen, as well as my fellow interns, particularly Sarah and Brian. Kwame and Omani (another Ghanaian carpenter) had previously built a form for a small structure on top of the wellhead. It had a bar to hang the submersible pump from. It would also protect the plumbing and electrical connections for the pump. On Friday, we poured the concrete into the form, so the pump house would be ready after the weekend.

Kwame practices testing the panels and fuses in case there is a problem with the system in the future.

Technical Specifications

System Overview

System type: Off-grid, PV-direct water pumping

Location: Asakraka, Ghana

Solar resource: 4 Average daily peak sun hours

Well depth: 31 Feet

Static water level: 17 Feet

Photovoltaics

Modules: Two Sharp NE-80E1U, 80 W STC, 24 VDC nominal

Array: 160 W STC, 24 VDC nominal

Array disconnect/overcurrent protection: 16 A breaker for disconnect with additional 7 amp automotive fast-blow fuse in-line with pump

Array installation: DP&W pole-mount, 15 degree tilt angle

Pump Details

Pump: Shurflo 9300 submersible

Pump design: Positive displacement 3-chamber diaphragm pump

Typical applications: Potable water well pump

Materials: High strength engineered plastics, stainless steel fasteners

Motor: Permanent magnet, PIN 11 126-10 (thermally protected)

Nominal voltage: 24 VDC

Maximum current: 4.0 A

Maximum lift: 230 Feet

Maximum submersion: 230 Feet

Outlet port: 1/2 Inch (12.7 mm) barbed fitting for 1/2 inch I.D. tubing

Inlet: 50 Mesh stainless steel screen

Weight: 6 Pounds (2.7 kg)

By mid-afternoon, the ditching was all finished. So we started on the next part of the project, gluing the PVC water pipe. This was a fun time, because in addition to all the rest of the workers, the Ghanaian children jumped in to help. They'd already been helping with the ditches at times, but now they were really in the middle of things. They were good at it too.

Either they had done this before, or they were very smart, or both! We were all glad that even the children had an interest in the system. After all, it would benefit them in many ways. At day's end, the pipe was all glued, the ditches were backfilled, and the three spigots were all set up, just waiting for the water to flow…

The completed "pump house." The electrical connections are on the left, the plumbing is on the right, and the pump is hanging from the bar in the middle.

Installing the Panels

After a weekend of other projects and responsibilities, we went to work Monday morning. A hired crew of masons stripped the forms from the concrete at the pump house down at the wellhead. Next on the agenda was putting up the panels—a moment that we'd all been waiting for. Kwame, Omani, another Ghanaian, and I worked on the roof. Brian and Sarah helped to hand the two panels and tools up to us. Kelly and Rachel took pictures, while everyone else helped in whatever way was needed, and watched.

The crew on the roof first put the rack together. The Direct Power rack was simple and sturdy, and we had no problems assembling it. I tried to take a backseat in the process as much as possible, letting the Ghanaians put it together. They were so good at doing everything that all I needed to do was provide some general direction, and they were off and running.

We set the tilt angle on the rack to 15 degrees to maximize output in winter, and rotated the rack to face a few degrees to the west of due south. This would provide the most output in Ghana's rainy season, when it's often raining in the morning, but usually clear in the afternoon.

After the rack was set up, Brian and Sarah handed up the first panel, which we bolted on with no trouble. The second panel followed soon after. When both panels where secured on the rack, we connected the 12 VDC nominal panels in series, so they could power the 24 volt Shurflo pump. This was an easy process, since the Sharp panels have MC connectors. All you have to do is push the connectors firmly together and the connection is made. To make the connection more secure, we also taped around each connector. After connecting the ground wire to the panels, we used zip ties to attach the wires to the rack and pole, and headed down the ladder to the disconnect box.

Successful Testing

When we measured the output from the panels, all was well. They were producing approximately what I'd expected, given the high temperature that day. Kwame and I worked for some time making the connections in the disconnect box. Because of the extra complication and expense of a float switch, the system was designed for manual control. When the water storage tank fills, the Ghanaians can flip a switch to turn off the pump. When they need more water, they can turn the pump back on.

Because of the simple design, there wasn't that much to show Kwame—just a locally obtained breaker for a disconnect, and a fuse to protect the pump in case it failed. We wired the positive leg from the panels to the wire running to the pump, after first running through the fuse and disconnect. The negative from the panels was wired directly to the negative terminal on the pump.

It was late afternoon by this time. But before the sun went down, I was able to make measurements down at the wellhead. Yes, the connections were all correct. Now that the solar-electric panels and wiring to the pump were done, there was only one more major part of the project to finish—installing the pump. There was only one hitch—we'd have just one day to do it!

Preparing the Pump

Tuesday morning, I worked with Kwame and another local man to disassemble and reassemble the pump, so they would know how to maintain the pump, and repair it in case of any malfunctions. The Shurflo pump can be easily rebuilt, and I'd brought along various extra parts kits, so that they would have all that they needed to fix the pump. I'd also brought a multimeter and a few other specialized tools that would be hard to obtain in Ghana. Kwame was trained as a carpenter, not an electrician, and this made the process of working on the pump slightly unfamiliar, but he caught on quickly. By the time the pump was successfully reassembled, he had a good grasp of how it all worked.

The kids at the school help glue PVC pipe. After just a few minutes of instruction, they were gluing like pros!

When we were done, Kwame had some other duties to attend to. Laura, Kelly, and I worked to connect the submersible cable, outlet hose, and safety rope to the pump. We then secured these three together with wire ties, while the Ghanaian teachers and children watched, asking us what we were doing. We cut the outlet hose and cable to approximately the correct length, and headed down to the wellhead to install the pump.

There was quite a crowd at the well. Rev. Gyamfi, Kwame, and the other workmen were there, as well as my five fellow interns, and teachers and students from the school. After getting the wires to the pump stripped and ready to go, I carefully lowered the pump into the well. I hung the safety rope on the bar that had been built for the purpose. It took a few minutes to get the electrical connections made. I was working with four fairly large wires in a small box, which can be a slightly frustrating experience. But soon, the connections were made and sealed with silicone, and the box was securely closed.

PV Pumping System Costs

Item	Cost (US$)
2 Sharp NE-80E1U PV modules	$568.00
Shurflo 9300 submersible pump	484.00
Shurflo spare parts	309.00
Shipping & transportation	267.69
PVC pipe & misc. plumbing	195.37
Cable, conduit, J-boxes, disconnects, fuses	181.97
Tools, misc. electrical, & other supplies	114.52
Polyurethane water tank, 450 gal.	103.70
Direct Power & Water top-of-pole mount	80.50
Total	$2,304.75

The System Today

When Reverend Gyamfi recently visited the U.S., I was able to hear a full report on the solar water pumping system. It's been running well, with absolutely no problems. They have always had enough water, even during cloudy periods. In fact, Gyamfi said that they have to turn the pump off frequently. A 12 foot (3.6 m) stand has been built for the tank, to provide better water pressure. All in all, Reverend Gyamfi and the Asakraka New Church School seem very pleased with the system.

Acknowledgements

This project could never have happened without the support of many wonderful people and organizations. I'd like to thank Dr. Bill Radcliffe and the New Uses Foundation for their solid support, and Reverend Martin Gyamfi and Kwame for their help getting materials, installing the system, and doing whatever else needed to be done.

I'd also like to recognize the church's outreach office and the college for sponsoring the internship. And last, but certainly not least, I'd like to thank my five fellow interns, Rachel Gardam, Laura Gladish, Brian Smith, Kelly Waddell, and Sarah Walker. I couldn't have done it without you. And to all the Ghanaians who helped, encouraged, and aided the whole process, thanks—you made the whole experience worthwhile.

Water at the Wellhead

I made the last connection, and the pump started up! The water poured out, and there were smiles all around, with excited children forming a ring around the well. Reverend Gyamfi got into the action too, posing with the water and beaming from ear to ear.

The pump was working, but the pipe still needed to be tested. We stopped the pump, and connected the outlet hose to the pipe running to the tank. Then we had to wait for the water to travel from the well to the tank, a height of about 140 feet (43 m), and a distance of about 500 feet (152 m). We did get some water up to the tank site, but we ran out of sun for the day before we could get it all set up and tested.

I knew that I would have limited time to test the system the next morning before we had to leave Asakraka. Before we went home for the evening, I spent a little time with Kwame and Omani, showing them some more possible problems that could occur with the panels, adjusting the rack to its final position, and explaining to Kwame how he could adjust the rack if the output was unsatisfactory. As I walked home in the dusk, I wracked my brain, making sure that I wasn't forgetting to do something important.

The Morning Brings Success

The morning was a blur. As soon as I got to school, I turned on the pump. While waiting for the water to reach the top, I worked with Kwame at the disconnect box, showing him how to troubleshoot various problems. Soon the water was flowing at the tank! Just then, Reverend Nicolas Anochi, a Ghanaian pastor who would be our ride back from Asakraka, arrived. He came and joined Kwame, my five fellow interns, and me, as we watched the water pour out in a steady stream. I was so relieved that it was all working as planned. We attached a short hose to the outlet pipe, and started to fill the tank.

Down at one of the spigots, Reverend Gyamfi turned on the water. It was running! The kids gathered round in excitement, posing for the photos that we were taking. At the same time, Reverend Anochi told us it was time to leave, and headed towards the pickup truck. We all shook hands with Reverend Gyamfi, bid farewell to teachers, and hugged kids as we walked to the truck.

The kids ran after us as we drove down the school driveway. We waved goodbye until the school was out of sight. As we neared the end of the church driveway, I caught a last glimpse of the Asakraka church and school, with the beautiful landscape in the background. Turning the corner, I thought I saw the sun glint off two panels nestled just above the African jungle.

Access

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