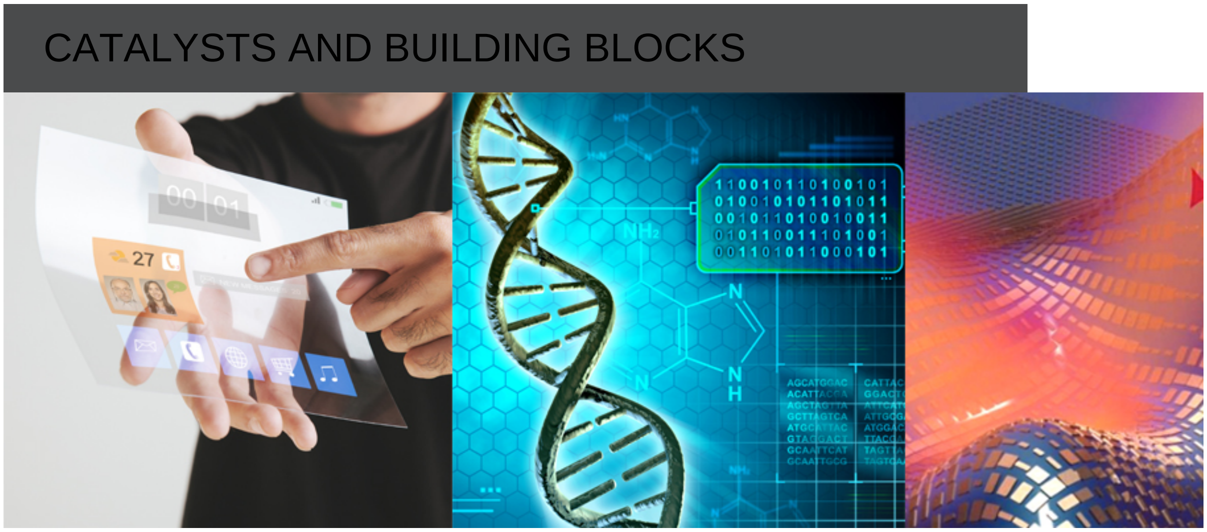
Catalysts and Building Blocks



2020

2021-2022

2023-2024

2025+

New technologies to harvest ambient energy such as light, vibration, flow, motion, pressure, magnetic fields, RF, automobile exhaust etc., will enable "battery-free" devices with semi-infinite connected life that can be installed permanently. Current energy harvesting technology capable of generating a few milliwatts (most sources) to a few watts (e.g., thermal) will give way to orders of magnitude greater capability. This will enable the proliferation of connected sensors beyond the projections for current "Internet of Things" technologies. In 2018, ON Semiconductor introduced a Bluetooth Low Energy (BLE) switch reference design, a platform that operates entirely on harvested energy. These system on chip designs will enable battery-less and entirely self-powered Bluetooth 5 IoT devices.

Graphene is a substance composed of pure carbon with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet. With a 1-square-meter sheet weighing only 0.77 mg, the material is incredibly light yet strong. Potential applications are incredibly diverse and include components with higher strength-to-weight ratios, lower cost solar cells, lower cost display screens in mobile devices, storing hydrogen for fuel cell-powered cars, medical sensors, faster charging batteries, ultra-capacitors, chemical sensors and many others. British sportswear brand inov-8 is incorporating graphene into a new running shoe to make them more flexible and stronger than traditional running shoes. Silicene is a silicon-based equivalent to carbon-based graphene with potential for atomic-level semiconductor logic.

Metamaterials are engineered to have properties not yet found in nature. These designed structures' shapes, geometry, sizes, orientations and arrangements give metamaterials unique properties capable of manipulating electromagnetic waves — by blocking, absorbing, enhancing, or bending waves. One can envision wave-bending devices that can facilitate RF transmission around corners and obstacles. In academia, rudimentary cloaking devices have been demonstrated and miniaturized antennas are being implemented, but this technology is still in its infancy.

Quantum Information Processing (QIP) is a domain which combines computer science with quantum physics to extend the capabilities of information processing. Based on the novel encoding of data on qubits, QIP can solve problems much faster (in an unconventional fashion) than classical information processing. An example of QIP is provided by the recent implementation of a quantum neural network (QNN) prototype by NTT which can operate at room temperature.

As sensors and actuators become a natural part of personal and public things, streams of data can be passively collected creating opportunities for the network itself to make real-time, autonomous decisions (improving efficiency and QoS). Looking at swarm behavior of animal species, like ants, herds, or flocks of birds, UC Berkeley's Swarm Lab is examining what can be leveraged from the world of nature into future theories for data flow and network efficiency.

These devices integrate electrical and mechanical functionality on the nano scale. MEMS typically integrate transistor-like nanoelectronics with mechanical actuators, pumps, or motors, and may thereby form physical, biological, and chemical sensors. DNA based nano machines will one day replace toxic chemotherapy drips, for example, and change the way therapies are delivered in the future.

Advances in materials technology are enabling high energy Li-air batteries which promise an energy density that rivals gasoline, offering a five-fold increase compared to traditional Li-Ion batteries. By using atmospheric oxygen instead of an internal oxidizer, these batteries could dramatically extend the time between re-charging.

Community labs and biohacker spaces, like Genspace and BioCurious, are emerging everywhere enabling rapid prototyping and experimentation by bio designers whose goal is to create more sustainable and healthier versions of existing and new products. Bolt Threads is disrupting textiles by engineering silk-inspired polymers (inspired by how spiders produce natural silk fibers). Future materials will be “programmed” with different properties including UV resistance, stretchiness, and strength. Another example is bio-concrete , engineered as regular concrete with a healing agent mixed in.

New nanotechnology advances are unearthing new forms of power generation through materials, such as Molybdenum Disulfide, which provide many multiples of the power generation density of traditional and evolutionary battery materials. Through single molecular layer materials, combined with nanopores, electricity can be stored and generated using osmotic pressure and salt solutions. Additionally, logic gates have been constructed using these materials and techniques, creating the potential for self-powered circuits.

Encoding of data in DNA grows data storage density orders of magnitudes beyond current semiconductor capabilities. Harvard researchers have already stored 700TB of data into a gram of DNA.

Today’s renewables are faced with fundamental reliable storage and supply challenges. The sun does not always shine for solar. The wind does not always blow for windmills. Storage batteries are expensive and large. What is needed is a distributed electricity storage system and an intelligent way to interconnect and control the distributed storage across utility companies. Operators are uniquely suited to deploy small electrical storage units along their network, close to distributed renewable energy generators and carrying the control signaling required to manage the intelligent renewable power storage and distribution system. To scale, operators can federate to provide cross-regional and transcontinental control signaling for multiple interconnected electric utilities.

Classical information is encoded with binary “bits” of 1s and 0s. In contrast, quantum computers operate with “qubits” which enable them to process multiple operations simultaneously. Quantum computing promises to dramatically speed up processing for crypto-security applications which factor very large numbers, as well as, for other hard optimization problems. IBM currently provides a 16-qubit quantum computer , in the cloud, for use in experiments. Affordable and commercially available quantum computers will be slow to emerge because quantum computers need to operate at absolute zero temperatures.

Sometimes referred to as brain-computer interfaces (BCIs), this growing field includes tiny neurotransmitters that are medically inserted into a patient’s nervous system or brain tissue in the hopes of improving cognitive or sensory-motor function. While there is a tendency to think this is a new field, early examples of BCIs are cochlear implants used to improve hearing. Recent research at Duke University used BCIs and VR to help paraplegics regain sensation and muscle control. Additional research is underway to determine whether BCIs can significantly help stroke victims recover. Nissan is also testing a neural interface called B2V (brain to vehicle) which enables brain control of steering, braking, and cabin controls.

Bees use chemicals in pheromones today to communicate to their hive. What if we could program biological molecules (bio-nanomachines) to use chemical signals to encode and transmit information as well as coordinate activity? Inspired by nature, the advantages provided by this “molecular” approach are size, biocompatibility, and biostability. Molecular communications are especially suited to scenarios where radio sensors and electromagnetic waves won't work, for example in underground structures like tunnels, underwater, in the human body, or in disaster situations where people are trapped under rubble.

4D printed objects are 3D printed objects that can change their shape, post-production. Sensationalized in science fiction stories dating back to 1943, self-replicating robots and weapons have been featured in box office hits such as the Matrix and The Terminator. In the real world of programmable materials, engineers are experimenting with using magnetics to enable machines to replicate themselves. One underlying approach uses smart grains of sand to self-replicate objects by selectively attaching to each other. MIT's self-assembly lab is currently working on an experiment called Self-Replicating Spheres .