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Memory Allocation in Intermittent Computing

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1. CONTEXT

Battery-free sensing devices can operate in inaccessible locations (space, civil buildings) without the need of maintenance. They are equipped with the following:

- An **energy harvester** (solar panel, piezogenerator ...) that harvest energy from its environment
- An **energy buffer** (supercapacitor) to buffer the small amount of energy harvested
- A normally-off **microcontroller**, executing short burst of computations with the buffered energy

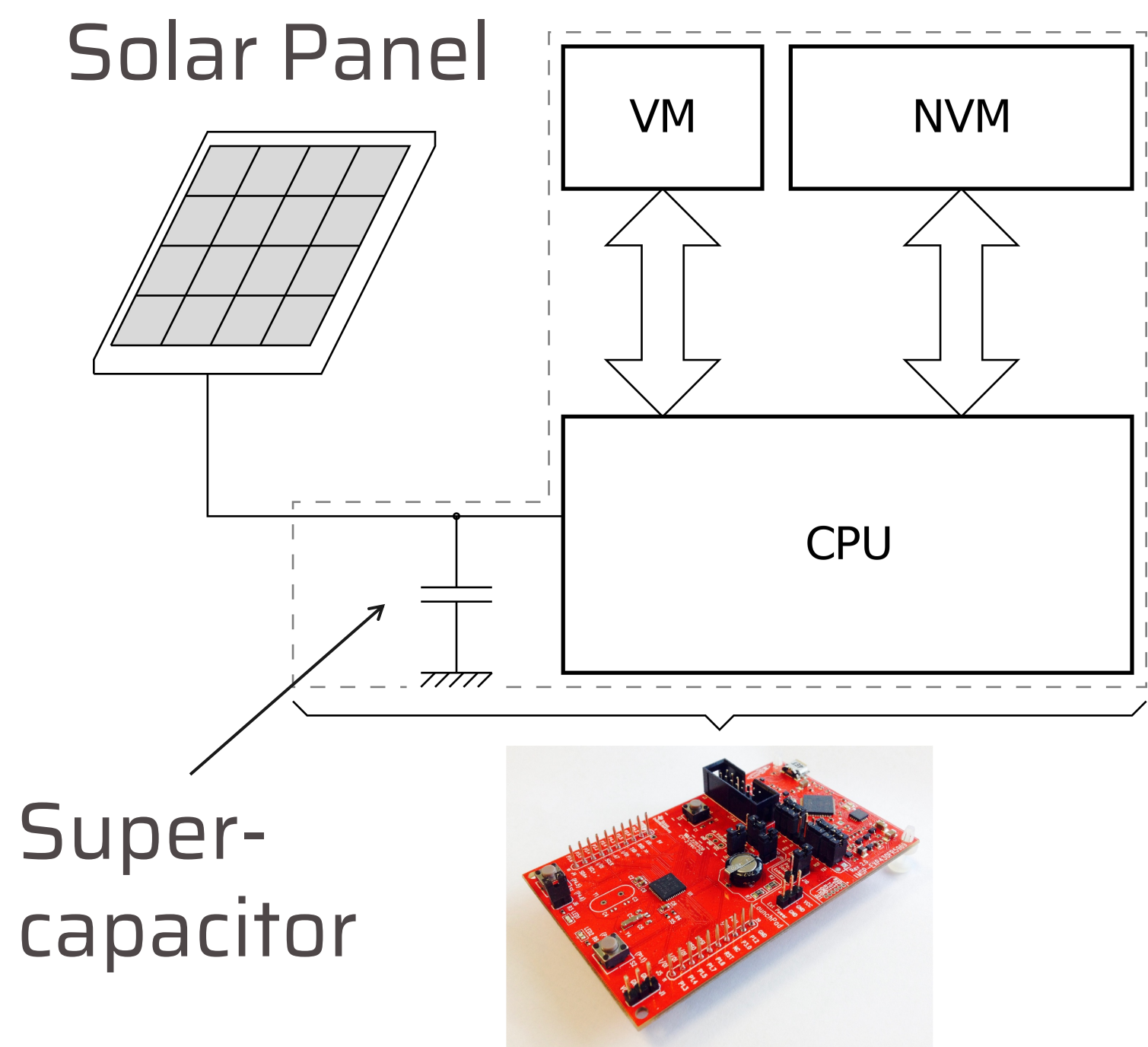


Figure 1 Architecture of an intermittent system

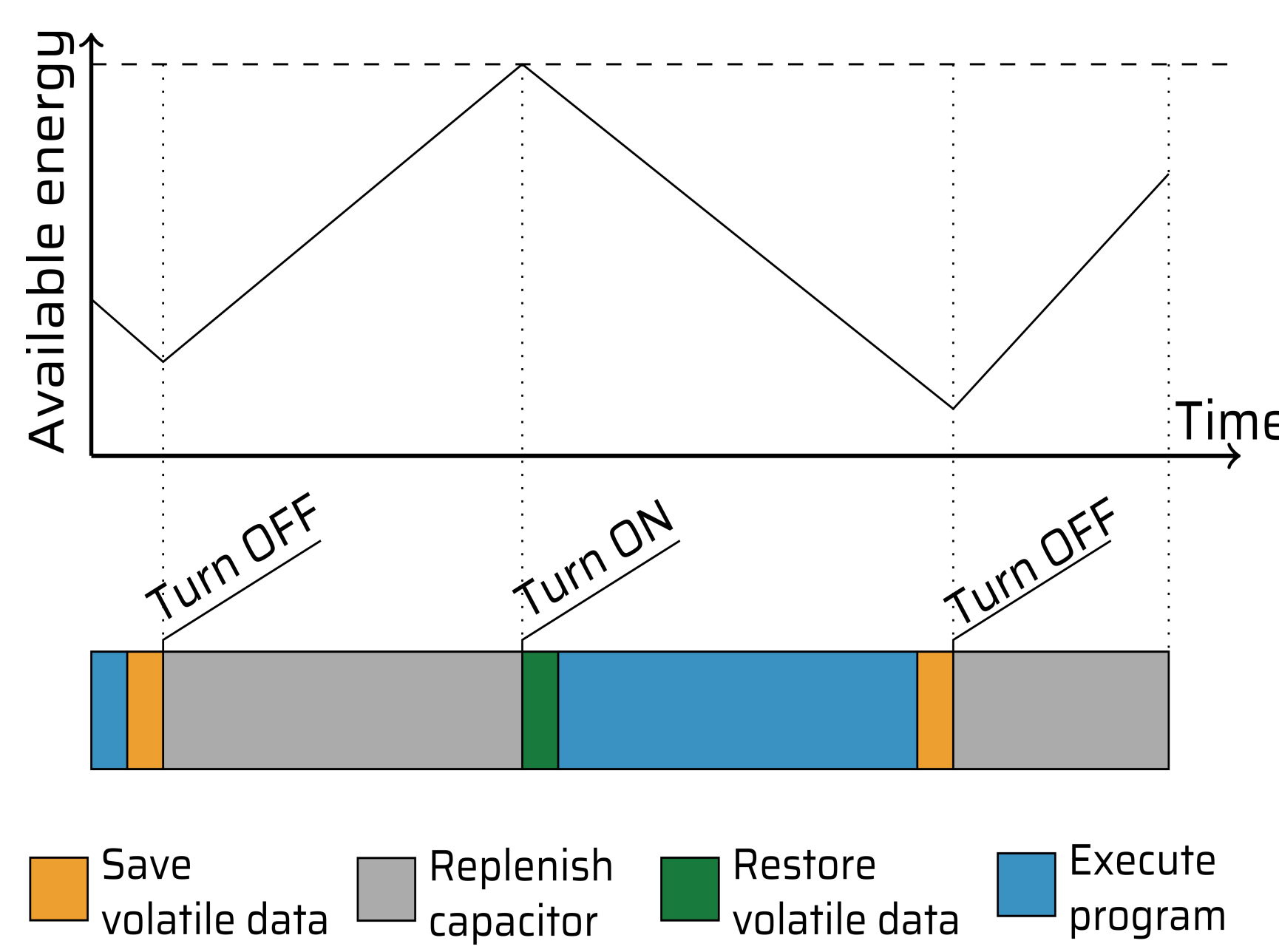


Figure 2 Intermittent execution

2. CHECKPOINT PLACEMENT AND MEMORY ALLOCATION

Problem: progress is lost on power off since volatile memory (VM) is erased

→ **Solution:** Insert instructions in the program binary to save checkpoints in non-volatile memory (NVM)

↳ Where?

Should variable be stored in VM or in NVM?

↳ In VM -> Low energy accesses (2.5x less than NVM accesses)

↳ In NVM -> No checkpointing overhead

```

int sum = 0; // Save checkpoint here?
for(int i = 0; i < SIZE; i++)
    sum += array[i]; // Save checkpoint here?
/* ..... */ // Save checkpoint here?
int a = f(sum); // Store in VM or NVM?
    
```

3. OUR SOLUTION: SCHEMATIC

Our goals:

- Take into account volatile memory size
- Ensure program termination
- Reduce energy consumption

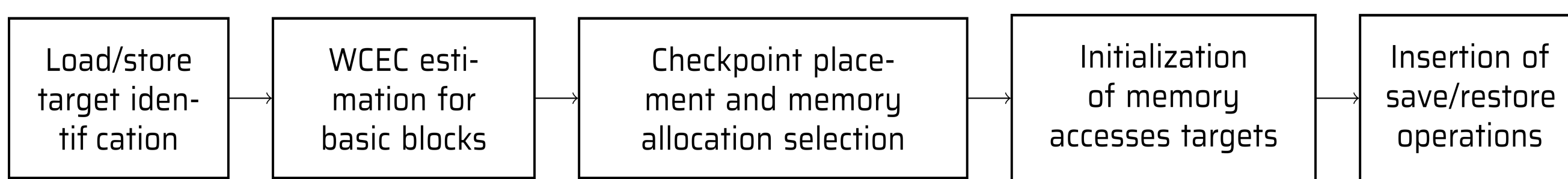


Figure 3 SCHEMATIC pipeline

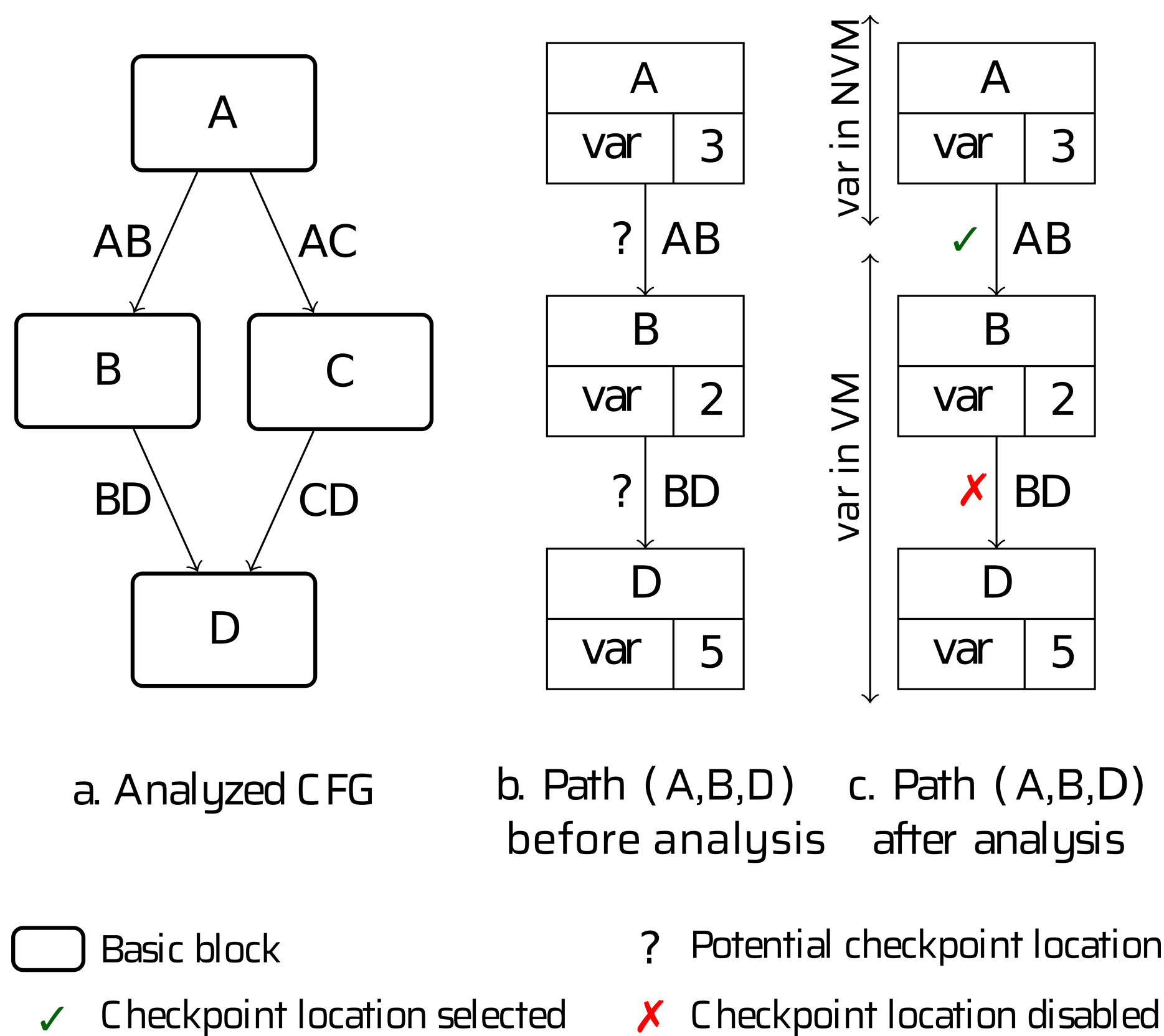


Figure 4 Analysis of a program using its CFG representation

4. RESULTS

	Benchmarks (MiBench Suite)		
	CRC	AES	FFT
Ratchet (all-NVM)	✓	✓	✓
Mementos (all-VM)	✓	✓	✗
Alfred	✓	✓	✗
SCHEMATIC	✓	✓	✓

Figure 5 Ability of solutions to run on a microcontroller with a limited volatile memory (MSP430FR5969: 2kB VM, 64kB NVM)

1.68x less energy consumed with our solution on average

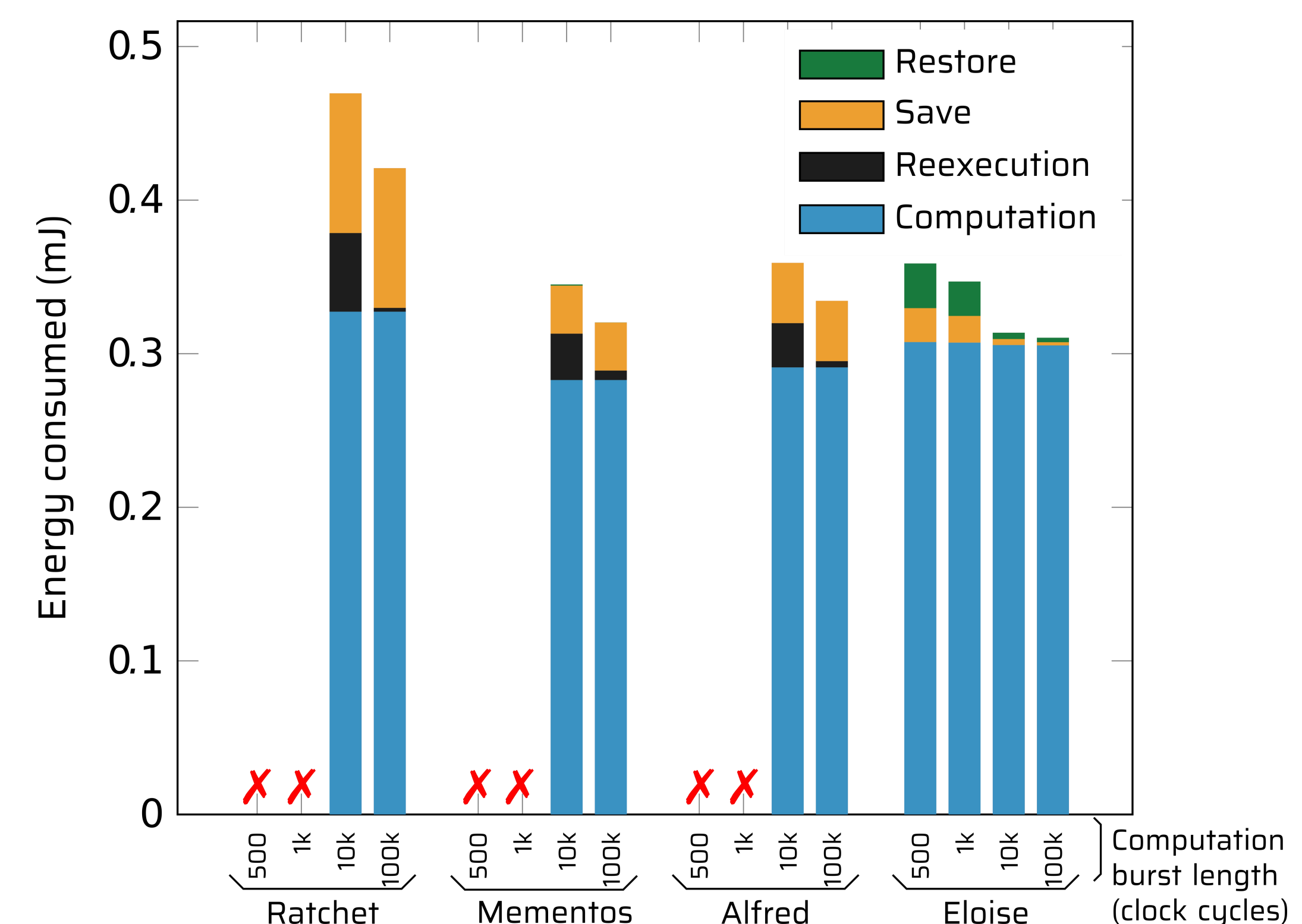


Figure 6 Energy consumption of SCHEMATIC in comparison to other solutions. ✗ means that the baseline could not execute

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- (3) Maioli, A.; Mottola, L. ALFRED: Virtual Memory for Intermittent Computing. SenSys '21; 2021
- (4) Reymond, H & al. SCHEMATIC: Compile-time Checkpoint Placement and Memory Allocation for Intermittent Systems. CGO'24; 2024