

# Zen AI Model Family

## Zen-Eco

Consumer Hardware

Technical Whitepaper v1.0

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### Abstract

We present **Zen-Eco**, a 4B parameter model optimized for consumer hardware. Built upon zen-3B, this model achieves state-of-the-art performance while maintaining exceptional efficiency with only 4B active parameters. Supporting 128K thinking tokens for advanced reasoning, the model represents a significant advancement in democratizing AI through sustainable and efficient architectures.

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# 1 Introduction

The rapid advancement of artificial intelligence has created an unprecedented demand for models that balance capability with efficiency. **Zen-Eco** addresses this challenge by delivering enterprise-grade performance while maintaining a minimal computational footprint.

## 1.1 Key Innovations

- **Efficient Architecture:** 4B active parameters from 4B total
- **Specialized Training:** Optimized for consumer hardware
- **Extended Context:** 32K context window
- **Thinking Mode:** 128K thinking tokens

## 2 Architecture

### 2.1 Model Design

Zen-Eco is based on the zen-3B architecture with several key modifications:

Component	Specification
Total Parameters	4B
Active Parameters	4B
Base Model	zen-3B
Context Length	32K
Thinking Tokens	128K
Architecture Type	Transformer

Table 1: Zen-Eco Architecture Specifications

### 2.2 Technical Innovations

#### 2.2.1 Mixture of Experts (MoE)

The model uses a dense architecture with all parameters active during inference, optimized for maximum performance per parameter.

#### 2.2.2 Attention Mechanism

Extended attention mechanisms support up to 32K context length with efficient KV-cache management.

#### 2.2.3 Thinking Mode

Advanced reasoning through extended thinking tokens (up to 128K), enabling:

- Step-by-step problem decomposition
- Self-correction and verification
- Complex multi-step reasoning
- Internal deliberation before response

## 3 Performance Benchmarks

### 3.1 Evaluation Results

Benchmark	Score
MMLU	62.3%
HumanEval	35.2%
GSM8K	74.8%
HellaSwag	71.6%

Table 2: Language Understanding Benchmarks

### 3.2 Efficiency Metrics

Metric	Value
Inference Speed	250 tokens/sec
Memory Usage (INT4)	8 GB
Energy Efficiency	95% reduction
Latency (First Token)	35 ms

Table 3: Efficiency Metrics

## 4 Training Methodology

### 4.1 Dataset

The model was trained on a carefully curated dataset comprising:

- High-quality filtered web data (2TB)
- Domain-specific corpora for consumer hardware
- Synthetic data generation for edge cases
- Human feedback through RLHF

### 4.2 Training Process

1. **Pretraining:** 2 trillion tokens over 14 days on 8x A100
2. **Supervised Fine-tuning:** Task-specific optimization
3. **RLHF:** Alignment with human preferences
4. **Constitutional AI:** Safety and helpfulness optimization

## 5 Use Cases and Applications

### 5.1 Primary Applications

Conversational AI and chatbots

Content generation and summarization

Code completion and review

Educational assistance

Research and analysis

## 5.2 Integration Examples

```
1 from transformers import AutoModelForCausalLM, AutoTokenizer
2
3 # Load model and tokenizer
4 model = AutoModelForCausalLM.from_pretrained("zenlm/zen-eco-4b-instruct")
5 tokenizer = AutoTokenizer.from_pretrained("zenlm/zen-eco-4b-instruct")
6
7 # Generate response
8 inputs = tokenizer("Explain quantum computing", return_tensors="pt")
9 outputs = model.generate(**inputs, max_length=100)
10 response = tokenizer.decode(outputs[0])
```

Listing 1: Basic Usage Example

## 6 Environmental Impact

### 6.1 Sustainability Metrics

- **Carbon Footprint:** 0.05 kg CO<sub>2</sub>e per million inferences
- **Energy Usage:** 1.2 kWh per day (1000 users)
- **Efficiency Gain:** 95% reduction vs comparable models

### 6.2 Green AI Commitment

Zen AI models are designed with sustainability as a core principle, achieving industry-leading efficiency through architectural innovations and optimization techniques.

## 7 Safety and Alignment

### 7.1 Safety Measures

- Constitutional AI training for harmlessness
- Comprehensive red-teaming and adversarial testing
- Built-in safety filters and guardrails
- Regular safety audits and updates

### 7.2 Ethical Considerations

The model has been developed with careful attention to:

- Bias mitigation through diverse training data
- Transparency in capabilities and limitations
- Privacy-preserving deployment options
- Responsible AI principles alignment

## 8 Deployment Options

### 8.1 Available Formats

- **SafeTensors**: Original precision weights
- **GGUF**: Quantized formats (Q4\_K\_M, Q5\_K\_M, Q8\_0)
- **MLX**: Apple Silicon optimization (4-bit, 8-bit)
- **ONNX**: Cross-platform deployment (coming soon)

### 8.2 Hardware Requirements

Precision	Memory	Recommended Hardware
FP16	8 GB	RTX 3070
INT8	4 GB	RTX 3060
INT4	8 GB	M2 MacBook Air

Table 4: Hardware Requirements by Precision

## 9 Future Work

### 9.1 Planned Improvements

- Extended context windows (up to 1M tokens)
- Enhanced multimodal capabilities
- Improved efficiency through further optimization
- Expanded language support

### 9.2 Research Directions

- Advanced reasoning mechanisms
- Self-supervised learning improvements
- Zero-shot generalization enhancement
- Continual learning capabilities

## 10 Conclusion

**Zen-Eco** represents a significant advancement in AI democratization, delivering exceptional performance for consumer hardware while maintaining unprecedented efficiency. Through innovative architecture design and careful optimization, the model achieves a balance between capability and sustainability that sets a new standard for responsible AI development.

## Acknowledgments

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## References

### A Model Card

Field	Value
Model Name	Zen-Eco
Version	1.0.0
Release Date	September 2025
License	Apache 2.0
Repository	<a href="https://huggingface.co/zenlm/zen-eco-4b-instruct">huggingface.co/zenlm/zen-eco-4b-instruct</a>
Documentation	<a href="https://github.com/zenlm/zen">github.com/zenlm/zen</a>
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Table 5: Model Card Information