

## Supplementary Material

### S.1. Limitations

Although our method is a simple and competitive approach to various OOD detection tasks, additional auxiliary data is still required. OOD detection without additional data would be an ideal model. However, approaches that use auxiliary data still show superior performance to the approaches without using auxiliary data. Instead, we can consider a way to utilize a small amount of auxiliary data as little as possible with competitive performance in future work.

### S.2. Potential Negative Societal Impacts

OOD detection is a branch of anomaly detection. In vision tasks, anomaly detection typically plays a positive role in strengthening security in surveillance systems. However, indiscriminate abuse of automated surveillance systems can increase the surveillance of workers. Therefore, when our method is applied to a real environment, we ensure ours to be used only for the purpose of enhancing human safety without infringing on human privacy.

### S.3. Details on the setting of hyperparameter $\alpha$

As discussed in Section 3.2, we set the adaptive loss margin as  $\alpha \cdot Z_\gamma$ . More specifically, to standardize  $\alpha$ , we redesign  $\alpha$  as a relative offset from the baseline which the case of  $\gamma=0$ . Thus, we set  $\alpha \approx \beta \cdot K \cdot (m_{out} - m_{in})$ , where  $\beta$  is proportionality constant,  $K$  is a number of classes and  $m_{out} - m_{in}$  is energy distance between in-distribution and OOD, respectively. When  $\gamma=0$ , adaptive loss margin  $\alpha \cdot Z_\gamma$  become  $\beta \cdot (m_{out} - m_{in})$ , which is the relative offset proportional to  $\beta$ . As  $\beta$  increases, the sensitivity to  $\gamma$  increases, and even a small change in  $\gamma$  greatly changes the adaptive loss margin. Conversely, if we set  $\beta \approx 0$ , the sensitivity to  $\gamma$  becomes small, and even if  $\gamma$  increases, the adaptive margin approaches 0 regardless of this, so there is no difference from the original energy regularization loss  $L_{out,hinge}$ . Finally, we choose to use the appropriate  $\beta = 0.05$  with corresponding  $\alpha$  and adjust the hyperparameter  $\gamma$ . As seen in Table S.1 and Table S.2, AUROC and accuracy also show similar tendencies as discussed above.

Table S.1. Average AUROC (over 6 datasets) on CIFAR10-LT using ResNet18 depending on hyperparameter  $\gamma$  and  $\alpha$

Hyperparameter $\gamma$	Average AUROC						
	Hyperparameter $\beta$						
	0.0025	0.01	0.025	0.05	0.1	0.25	0.5
	Hyperparameter $\alpha$						
	0.5	2	5	10	20	50	100
0.1	91.92	91.93	91.98	92.01	92.12	92.02	91.52
0.25	91.96	92.00	92.07	92.16	92.28	92.42	91.69
0.5	92.17	92.20	92.29	92.44	92.55	92.11	91.85
0.75	92.34	92.39	92.48	<b>92.56</b>	92.50	92.00	91.82
1	92.41	92.47	92.52	92.45	92.44	91.91	91.79
1.25	92.39	92.41	92.37	92.33	92.27	91.94	91.61

Table S.2. Accuracy on CIFAR10-LT using ResNet18 depending on hyperparameter  $\gamma$  and  $\alpha$

Hyperparameter $\gamma$	Accuracy(ACC)						
	Hyperparameter $\beta$						
	0.0025	0.01	0.025	0.05	0.1	0.25	0.5
	Hyperparameter $\alpha$						
	0.5	2	5	10	20	50	100
0.1	74.53	74.60	74.84	75.03	75.45	73.71	70.18
0.25	74.57	74.64	74.86	75.23	75.95	76.13	63.15
0.5	75.15	75.23	75.61	75.92	<b>76.60</b>	68.03	59.78
0.75	75.88	75.87	76.29	76.22	74.87	65.64	56.92
1	76.15	75.92	75.98	74.85	72.40	62.86	54.66
1.25	75.94	75.66	74.61	72.38	69.96	60.85	52.43

## S.4. OOD prior probability for all tasks

### S.4.1 Semantic Segmentation

Table S.3. OOD prior probability in semantic segmentation task: cut-pasted OOD pixel inference result collected from 10000 synthesized scene images

class index	0	1	2	3	4	5	6	7	8	9
class name	road	sidewalk	building	wall	fence	pole	traffic light	traffic sign	vegetation	terrain
probability	1.53E-01	1.33E-02	1.07E-01	4.01E-02	3.39E-02	5.26E-03	1.06E-03	2.80E-02	8.02E-02	9.80E-02
class index	10	11	12	13	14	15	16	17	18	
class name	sky	person	rider	car	truck	bus	train	motorcycle	bicycle	
probability	2.17E-03	1.53E-01	2.92E-02	8.71E-02	1.20E-01	1.60E-02	7.07E-03	1.70E-02	9.39E-03	

### S.4.2 Long-tailed Image Classification

Table S.4. OOD prior probability in long-tailed image classification task: TinyImages 300K inference result on CIFAR10-LT model using ResNet18 :

class index	0	1	2	3	4	5	6	7	8	9
class name	airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
probability	2.50E-01	7.96E-02	1.63E-01	2.49E-01	6.15E-02	8.50E-02	3.05E-02	2.32E-02	2.39E-02	3.45E-02

Table S.5. OOD prior probability in long-tailed image classification task: TinyImages 300K inference result on CIFAR100-LT model using ResNet18

class index	0	1	2	3	4	5	6	7	8	9
class name	apple	aquarium.fish	baby	bear	beaver	bed	bee	beetle	bicycle	bottle
probability	7.58E-03	1.69E-02	6.16E-02	2.54E-02	1.78E-02	3.67E-02	2.81E-02	1.02E-02	1.87E-02	3.70E-02
class index	10	11	12	13	14	15	16	17	18	19
class name	bowl	boy	bridge	bus	butterfly	camel	can	castle	caterpillar	cattle
probability	2.98E-02	6.17E-02	3.48E-02	4.20E-02	1.69E-02	1.61E-02	6.56E-02	2.40E-02	2.52E-02	1.70E-02
class index	20	21	22	23	24	25	26	27	28	29
class name	chair	chimpanzee	clock	cloud	cockroach	couch	crab	crocodile	cup	dinosaur
probability	7.81E-03	7.30E-03	2.55E-02	1.84E-02	3.27E-03	2.78E-02	9.09E-03	1.17E-02	7.72E-03	9.21E-03
class index	30	31	32	33	34	35	36	37	38	39
class name	dolphin	elephant	flatfish	forest	fox	girl	hamster	house	kangaroo	keyboard
probability	8.08E-03	7.00E-03	9.30E-03	2.38E-02	3.79E-03	1.99E-02	4.01E-03	1.64E-02	6.19E-03	1.74E-02
class index	40	41	42	43	44	45	46	47	48	49
class name	lamp	lawn.mower	leopard	lion	lizard	lobster	man	maple.tree	motorcycle	mountain
probability	1.59E-02	6.44E-03	7.91E-03	2.53E-03	6.93E-03	7.94E-03	1.97E-02	4.40E-03	3.35E-03	8.74E-03
class index	50	51	52	53	54	55	56	57	58	59
class name	mouse	mushroom	oak.tree	orange	orchid	otter	palm.tree	pear	pickup.truck	pine.tree
probability	2.52E-03	4.93E-03	1.88E-03	2.78E-03	5.78E-03	1.05E-03	2.04E-03	1.31E-03	2.52E-03	2.38E-03
class index	60	61	62	63	64	65	66	67	68	69
class name	plain	plate	poppy	porcupine	possum	rabbit	raccoon	ray	road	rocket
probability	1.14E-02	1.46E-02	3.08E-03	1.42E-03	4.73E-03	7.11E-03	3.10E-03	5.36E-03	4.87E-03	9.77E-03
class index	70	71	72	73	74	75	76	77	78	79
class name	rose	sea	seal	shark	shrew	skunk	skyscraper	snail	snake	spider
probability	1.94E-03	3.22E-03	4.47E-04	9.43E-04	2.63E-04	3.23E-04	2.14E-03	1.33E-04	1.59E-03	8.27E-04
class index	80	81	82	83	84	85	86	87	88	89
class name	squirrel	streetcar	sunflower	sweet.pepper	table	tank	telephone	television	tiger	tractor
probability	2.10E-04	1.89E-03	1.05E-03	4.87E-04	1.35E-03	3.57E-04	1.10E-03	3.32E-03	4.07E-04	2.84E-03
class index	90	91	92	93	94	95	96	97	98	99
class name	train	trout	tulip	turtle	wardrobe	whale	willow.tree	wolf	woman	worm
probability	7.27E-04	7.00E-05	9.33E-05	2.00E-05	2.87E-03	1.60E-04	2.43E-04	5.33E-05	4.03E-04	9.00E-05

### S.4.3 Image Classification

Table S.6. OOD prior probability in image classification task: TinyImages 300K inference result on CIFAR10 model using ResNet18

class index	0	1	2	3	4	5	6	7	8	9
class name	airplane	automobile	bird	cat	deer	dog	frog	horse	ship	truck
probability	1.15E-01	3.62E-02	9.94E-02	2.04E-01	3.58E-02	1.19E-01	7.51E-02	5.35E-02	9.91E-02	1.62E-01

Table S.7. OOD prior probability in image classification task: TinyImages 300K inference result on CIFAR100 model using ResNet18.

class index	0	1	2	3	4	5	6	7	8	9
class name	apple	aquarium_fish	baby	bear	beaver	bed	bee	beetle	bicycle	bottle
probability	1.39E-03	1.60E-03	1.50E-02	6.34E-03	2.66E-03	1.15E-02	3.01E-03	2.50E-03	5.32E-03	1.88E-02
class index	10	11	12	13	14	15	16	17	18	19
class name	bowl	boy	bridge	bus	butterfly	camel	can	castle	caterpillar	cattle
probability	1.98E-02	1.97E-02	1.69E-02	1.36E-02	4.82E-03	5.97E-03	4.14E-02	1.24E-02	9.66E-03	1.01E-02
class index	20	21	22	23	24	25	26	27	28	29
class name	chair	chimpanzee	clock	cloud	cockroach	couch	crab	crocodile	cup	dinosaur
probability	7.11E-03	4.63E-03	2.11E-02	1.93E-02	2.88E-03	2.62E-02	4.44E-03	4.88E-03	7.81E-03	3.48E-03
class index	30	31	32	33	34	35	36	37	38	39
class name	dolphin	elephant	flatfish	forest	fox	girl	hamster	house	kangaroo	keyboard
probability	1.46E-03	5.00E-03	1.37E-02	2.69E-02	2.08E-03	1.68E-02	1.25E-03	2.83E-02	4.45E-03	2.18E-02
class index	40	41	42	43	44	45	46	47	48	49
class name	lamp	lawn_mower	leopard	lion	lizard	lobster	man	maple_tree	motorcycle	mountain
probability	2.38E-02	5.93E-03	3.82E-03	9.67E-04	9.30E-03	1.61E-02	7.35E-02	2.05E-03	8.32E-03	6.84E-03
class index	50	51	52	53	54	55	56	57	58	59
class name	mouse	mushroom	oak_tree	orange	orchid	otter	palm_tree	pear	pickup_truck	pine_tree
probability	3.60E-03	6.78E-03	8.63E-04	3.11E-03	1.05E-02	5.41E-03	3.04E-03	5.48E-03	6.31E-03	9.94E-03
class index	60	61	62	63	64	65	66	67	68	69
class name	plain	plate	poppy	porcupine	possum	rabbit	raccoon	ray	road	rocket
probability	1.14E-02	1.46E-02	3.08E-03	1.42E-03	4.73E-03	7.11E-03	3.10E-03	5.36E-03	4.87E-03	9.77E-03
class index	70	71	72	73	74	75	76	77	78	79
class name	rose	sea	seal	shark	shrew	skunk	skyscraper	snail	snake	spider
probability	4.86E-03	1.47E-02	4.44E-03	5.88E-03	1.82E-03	2.13E-03	8.50E-03	2.21E-03	8.53E-03	5.92E-03
class index	80	81	82	83	84	85	86	87	88	89
class name	squirrel	streetcar	sunflower	sweet_pepper	table	tank	telephone	television	tiger	tractor
probability	4.27E-03	1.23E-02	3.71E-03	9.63E-03	3.25E-02	1.06E-02	1.38E-02	2.93E-02	3.31E-03	1.12E-02
class index	90	91	92	93	94	95	96	97	98	99
class name	train	trout	tulip	turtle	wardrobe	whale	willow_tree	wolf	woman	worm
probability	8.04E-03	2.99E-03	6.48E-03	2.52E-03	2.10E-02	2.42E-03	9.76E-03	3.52E-03	2.64E-02	1.00E-02

## S.5. Detailed Experiment Results

### S.5.1 Semantic Segmentation

Table S.8. Detailed evaluation result in semantic segmentation task depending on  $\gamma$  : OOD detection performance(AUROC,AP,FPR) and accuracy(MIOU for Cityscapes validation) on the Fishyscapes validation sets and Road Anomaly test set

Method		City	FS Lost & Found			FS Static			Road Anomaly		
Name	$\gamma$	MIOU $\uparrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
EnergyOE	0.0	89.07	98.14	45.61	8.21	99.32	89.12	2.62	83.32	32.59	53.01
	1.0	89.04	98.01	50.42	8.87	99.34	89.28	2.33	83.61	30.73	49.96
	2.0	<b>89.83</b>	98.72	53.36	6.57	99.42	90.32	2.31	84.90	33.72	<b>46.39</b>
	3.0	88.91	98.42	<b>54.58</b>	6.70	<b>99.43</b>	<b>91.77</b>	<b>1.63</b>	<b>85.50</b>	<b>34.90</b>	46.60
EnergyOE	4.0	88.53	<b>98.81</b>	53.27	<b>5.18</b>	99.34	89.98	2.39	83.53	29.51	46.91
Inverse Balanced EnergyOE	-3.0	84.28	95.49	43.94	31.28	98.45	81.32	5.66	84.92	41.17	55.57

## S.5.2 Long-tailed Image Classification

### ResNet18 model on CIFAR10-LT:

Table S.9. Detailed evaluation result on CIFAR10-LT depending on  $\gamma$  : OOD detection performance (AUROC,AP, FPR) and classification accuracy (ACC) with model ResNet18; Mean over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR100; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365

(a)											
Method		ACC $\uparrow$	Texture			SVHN			CIFAR 100		
Name	$\gamma$		AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Energy OE	0.00	74.53	95.53	92.93	23.26	96.63	98.46	14.52	84.44	84.63	59.92
Balanced Energy OE	0.10	75.03	95.49	91.94	22.44	96.68	97.90	12.64	84.63	84.42	59.16
	0.25	75.23	95.55	91.63	22.03	96.99	98.06	11.82	84.89	84.40	57.80
	0.50	75.92	95.70	92.05	21.13	97.49	98.63	10.48	85.18	84.78	57.09
	0.75	<b>76.22</b>	95.69	92.38	21.26	97.74	98.89	9.87	85.20	84.98	57.95
	1.00	74.85	95.56	92.57	22.57	97.94	99.03	9.11	84.84	84.90	61.18
Inv-Balanced Energy OE	-0.75	64.24	95.19	92.14	27.52	96.59	98.48	18.89	81.76	81.91	63.45

(b)												
Method	Tiny ImageNet			LSUN			Place365			Average		
$\gamma$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
0.00	88.40	84.95	45.17	94.00	93.70	26.96	92.51	97.14	32.88	91.92	91.97	33.79
0.10	88.51	84.58	44.56	94.12	93.49	26.36	92.67	97.10	31.61	92.01	91.57	32.80
0.25	88.63	84.37	43.29	94.12	92.72	25.52	92.79	96.98	30.54	92.16	91.36	31.83
0.50	88.85	84.71	42.46	94.30	92.80	24.62	93.10	97.08	29.11	92.44	91.67	30.81
0.75	88.92	84.98	42.38	94.48	93.15	23.88	93.35	97.23	28.25	<b>92.56</b>	91.94	<b>30.60</b>
1.00	88.74	85.06	43.11	94.36	93.35	25.71	93.26	97.27	29.46	92.45	<b>92.03</b>	31.86
1.25	88.47	84.95	44.07	94.31	93.56	26.46	93.24	97.30	30.15	92.33	<b>92.03</b>	32.60
-0.75	86.70	82.96	50.86	93.10	92.86	36.08	91.14	96.62	42.15	90.75	90.83	39.82

Table S.10. Detailed evaluation result on CIFAR10-LT depending on  $\gamma$  : OOD detection performance (AUROC,AP, FPR) and classification accuracy (ACC) with model ResNet18; Std over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR100; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365

(a)											
Method		ACC↑	Texture			SVHN			CIFAR 100		
Name	$\gamma$		AUC↑	AP↑	FPR↓	AUC↑	AP↑	FPR↓	AUC↑	AP↑	FPR↓
Energy OE	0.00	3.09E-02	3.73E-03	8.98E-03	1.43E-01	3.82E-02	1.89E-02	1.14E-01	5.00E-03	5.00E-03	8.22E-02
Balanced Energy OE	0.10	2.63E-02	5.00E-03	1.11E-02	8.76E-02	2.97E-02	1.89E-02	1.52E-01	7.64E-03	9.43E-03	1.59E-01
	0.25	4.75E-02	6.87E-03	1.49E-02	8.96E-02	1.97E-02	1.73E-02	1.03E-01	1.00E-02	1.15E-02	8.42E-02
	0.50	4.83E-02	5.77E-03	2.13E-02	5.93E-02	1.61E-02	8.16E-03	8.55E-02	6.87E-03	1.29E-02	1.37E-01
	0.75	3.73E-02	8.98E-03	2.71E-02	1.30E-01	9.57E-03	6.87E-03	1.15E-01	5.77E-03	1.29E-02	1.79E-01
	1.00	5.15E-02	6.87E-03	2.21E-02	1.51E-01	1.41E-02	6.87E-03	9.36E-02	7.64E-03	8.98E-03	1.22E-01
	1.25	4.12E-02	1.07E-02	2.69E-02	1.13E-01	2.52E-02	1.49E-02	9.93E-02	8.98E-03	9.43E-03	1.28E-01
Inv-Balanced Energy OE	-0.75	4.89E-02	4.71E-03	7.45E-03	1.22E-01	2.11E-02	1.26E-02	1.39E-01	4.71E-03	4.71E-03	9.64E-02

(b)												
Method	Tiny ImageNet			LSUN			Place365			Average		
$\gamma$	AUC↑	AP↑	FPR↓	AUC↑	AP↑	FPR↓	AUC↑	AP↑	FPR↓	AUC↑	AP↑	FPR↓
0.00	5.00E-03	3.73E-03	1.03E-01	9.43E-03	9.57E-03	5.35E-02	3.73E-03	0.00E+00	6.47E-02	1.08E-02	7.70E-03	9.34E-02
0.10	9.57E-03	6.87E-03	1.46E-01	3.73E-03	8.98E-03	9.69E-02	5.00E-03	5.00E-03	6.59E-02	1.01E-02	1.00E-02	1.18E-01
0.25	5.00E-03	1.34E-02	3.65E-02	1.15E-02	1.26E-02	9.09E-02	8.16E-03	5.00E-03	7.69E-02	1.02E-02	1.25E-02	8.01E-02
0.50	3.73E-03	8.98E-03	5.21E-02	6.87E-03	1.21E-02	6.88E-02	7.45E-03	4.71E-03	5.98E-02	7.80E-03	1.14E-02	7.71E-02
0.75	1.11E-02	1.07E-02	1.16E-01	7.64E-03	1.34E-02	7.16E-02	4.71E-03	5.00E-03	1.38E-01	7.96E-03	1.27E-02	1.25E-01
1.00	7.64E-03	1.70E-02	4.16E-02	1.29E-02	1.89E-02	1.59E-01	4.71E-03	5.00E-03	4.74E-02	8.99E-03	1.31E-02	1.03E-01
1.25	9.43E-03	1.11E-02	6.99E-02	5.77E-03	8.98E-03	1.84E-01	5.00E-03	3.73E-03	5.43E-02	1.08E-02	1.25E-02	1.08E-01
-0.75	3.73E-03	6.87E-03	1.47E-01	3.73E-03	5.77E-03	7.29E-02	3.73E-03	5.00E-03	7.57E-02	6.96E-03	7.07E-03	1.09E-01

# ResNet18 model on CIFAR100-LT:

Table S.11. Detailed evaluation result on CIFAR100-LT depending on  $\gamma$  : OOD detection performance (AUROC,AP, FPR) and classification accuracy (ACC) with model ResNet18; Mean over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR10; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365

(a)

Method		ACC $\uparrow$	Texture			SVHN			CIFAR 10		
Name	$\gamma$		AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Energy OE	0.00	40.65	79.56	70.88	68.60	86.19	91.74	42.27	61.15	56.66	82.60
Balanced Energy OE	0.10	40.90	79.78	70.80	68.01	86.65	91.93	41.01	61.29	56.65	82.19
	0.25	41.50	80.06	69.91	66.93	86.91	91.99	39.46	61.24	56.51	82.23
	0.50	<b>41.64</b>	81.01	70.87	65.50	87.45	92.15	36.93	61.38	55.73	83.49
	0.75	41.05	82.10	73.09	64.19	88.66	92.88	33.79	59.40	54.97	85.16
	1.00	38.62	83.28	75.67	63.54	89.68	93.71	32.64	58.81	54.60	86.46
	1.25	36.51	84.33	77.49	62.14	90.71	94.48	30.90	58.29	54.30	87.42
Inv-Balanced Energy OE	-0.75	34.77	82.79	77.96	70.45	83.12	90.07	51.32	58.34	54.32	88.17

(b)

Method	Tiny ImageNet			LSUN			Place365			Average		
$\gamma$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
0.00	70.78	55.90	74.43	81.61	69.16	57.37	79.12	89.09	61.96	76.40	72.24	64.54
0.10	70.89	55.85	74.23	81.94	69.37	56.53	79.42	89.18	60.93	76.66	72.29	63.82
0.25	71.10	55.85	74.12	82.35	69.55	55.50	79.86	89.31	59.54	76.92	72.18	62.96
0.50	71.36	56.15	73.81	83.25	70.48	52.87	80.65	89.65	58.09	77.35	72.50	61.78
0.75	71.42	56.52	74.22	83.83	71.23	52.04	81.10	89.94	57.52	77.75	73.10	<b>61.15</b>
1.00	71.41	56.76	75.08	83.76	71.40	53.46	81.12	90.09	58.79	<b>78.01</b>	73.70	61.66
1.25	71.38	56.81	75.18	82.85	70.92	58.68	80.17	89.83	64.16	77.96	<b>73.97</b>	63.08
-0.75	69.27	55.59	77.09	80.20	68.79	66.63	77.09	88.64	70.64	75.14	72.56	70.71

Table S.12. Detailed evaluation result on CIFAR100-LT depending on  $\gamma$  : OOD detection performance (AUROC,AP, FPR) and classification accuracy (ACC) with model ResNet18; Std over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR10; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365

(a)

Method		ACC $\uparrow$	Texture			SVHN			CIFAR 10		
Name	$\gamma$		AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Energy OE	0.00	1.63E-02	3.73E-03	1.25E-02	4.22E-02	2.03E-02	1.41E-02	4.07E-02	4.71E-03	3.73E-03	2.93E-02
Balanced Energy OE	0.10	2.48E-02	1.12E-02	2.29E-02	6.19E-02	1.53E-02	1.11E-02	4.23E-02	0.00E+00	4.71E-03	2.92E-02
	0.25	2.91E-02	3.73E-03	6.87E-03	6.47E-02	1.86E-02	1.77E-02	8.08E-02	4.71E-03	5.00E-03	2.99E-02
	0.50	2.48E-02	9.57E-03	1.71E-02	5.16E-02	2.27E-02	1.61E-02	4.81E-02	4.71E-03	5.00E-03	4.36E-02
	0.75	3.64E-02	7.45E-03	1.25E-02	1.09E-01	1.95E-02	1.41E-02	2.11E-02	3.73E-03	3.73E-03	3.09E-02
	1.00	3.35E-02	9.43E-03	8.98E-03	1.06E-01	2.21E-02	1.38E-02	1.36E-01	5.77E-03	3.73E-03	4.35E-02
	1.25	3.83E-02	9.43E-03	1.15E-02	4.99E-02	2.13E-02	1.89E-02	8.65E-02	7.64E-03	9.57E-03	4.35E-02
Inv-Balanced Energy OE	-0.75	2.31E-02	4.71E-03	4.71E-03	2.81E-02	2.00E-02	1.26E-02	7.39E-02	7.11E-15	4.71E-03	2.08E-02

(b)

Method	Tiny ImageNet			LSUN			Place365			Average		
$\gamma$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
0.00	1.42E-14	4.71E-03	4.41E-02	0.00E+00	4.71E-03	9.09E-02	0.00E+00	1.42E-14	4.12E-02	4.80E-03	6.63E-03	4.81E-02
0.10	0.00E+00	3.73E-03	3.59E-02	5.00E-03	4.71E-03	8.35E-02	0.00E+00	5.00E-03	3.53E-02	5.24E-03	8.68E-03	4.80E-02
0.25	4.71E-03	4.71E-03	4.34E-02	3.73E-03	3.73E-03	4.14E-02	4.71E-03	3.73E-03	1.63E-02	6.70E-03	6.96E-03	4.61E-02
0.50	0.00E+00	4.71E-03	5.58E-02	4.71E-03	3.73E-03	6.15E-02	5.00E-03	3.73E-03	6.74E-02	7.78E-03	8.39E-03	5.47E-02
0.75	3.73E-03	6.87E-03	6.52E-02	0.00E+00	5.00E-03	7.91E-02	4.71E-03	5.00E-03	4.26E-02	6.52E-03	7.87E-03	5.80E-02
1.00	6.87E-03	1.07E-02	3.50E-02	5.77E-03	6.87E-03	4.78E-02	3.73E-03	4.71E-03	5.89E-02	8.95E-03	8.13E-03	7.11E-02
1.25	4.71E-03	4.71E-03	6.08E-02	1.07E-02	1.11E-02	3.73E-02	7.45E-03	0.00E+00	5.55E-02	1.02E-02	9.30E-03	5.56E-02
-0.75	0.00E+00	4.71E-03	2.67E-02	5.77E-03	6.87E-03	2.63E-02	4.71E-03	0.00E+00	3.89E-02	5.87E-03	5.60E-03	3.58E-02

### WideResNet model on CIFAR10-LT:

Table S.13. Detailed evaluation result on CIFAR10-LT depending on  $\gamma$  : OOD detection performance (AUROC,AP, FPR) and classification accuracy (ACC) with model WideResNet(WRN-40-2); Mean over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR100; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365

Method		ACC $\uparrow$	Texture			SVHN			CIFAR 100		
Name	$\gamma$		AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Energy OE	0.00	75.03	94.25	89.94	26.79	95.07	96.66	16.08	84.20	84.00	57.71
Balanced Energy OE	0.10	75.28	94.39	89.27	25.82	95.22	96.34	14.76	84.39	83.81	56.63
	0.25	75.74	94.32	88.57	25.55	95.43	96.33	13.87	84.60	83.64	55.22
	0.50	<b>76.14</b>	94.31	88.39	26.08	95.83	96.73	12.75	84.80	83.81	54.68
	0.75	74.76	94.23	88.75	26.51	96.23	97.12	12.24	84.50	83.66	56.59
	1.00	71.20	94.14	89.77	29.40	96.51	97.74	12.56	84.00	83.50	58.40
	1.25	68.70	94.06	90.32	31.19	96.63	98.11	13.97	83.60	83.33	59.46
Inv-Balanced Energy OE	-0.75	62.91	93.15	90.49	39.41	94.22	97.22	24.63	80.54	80.87	65.46

(a)

Method	ACC $\uparrow$	Tiny ImageNet			LSUN			Place365			Average		
$\gamma$		AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
0.00	75.03	87.63	83.86	47.77	94.80	94.41	24.17	92.72	97.17	31.58	91.44	91.01	34.02
0.10	75.28	87.82	83.75	46.80	94.78	93.81	22.68	92.84	97.06	29.98	91.57	90.67	32.78
0.25	75.74	87.97	83.61	45.47	94.72	93.03	21.51	92.89	96.89	28.90	91.65	90.34	31.75
0.50	<b>76.14</b>	88.12	83.76	44.61	94.90	93.23	20.45	93.16	96.96	27.61	<b>91.85</b>	90.48	<b>31.03</b>
0.75	74.76	87.91	83.71	45.68	94.94	93.67	20.91	93.19	97.05	28.25	91.83	90.66	31.69
1.00	71.20	87.59	83.56	47.68	94.91	94.25	22.63	93.19	97.21	29.08	91.72	91.01	33.29
1.25	68.70	87.22	83.42	48.87	94.81	92.28	23.16	93.06	97.22	30.14	91.56	<b>91.11</b>	34.46
-0.75	62.91	84.81	81.26	56.31	92.93	92.66	36.62	90.38	96.35	44.05	89.34	89.81	44.41

(b)

Table S.14. Detailed evaluation result on CIFAR10-LT depending on  $\gamma$  : OOD detection performance (AUROC,AP, FPR) and classification accuracy (ACC) with model WideResNet(WRN-40-2); Std over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR100; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365

Method		ACC $\uparrow$	Texture			SVHN			CIFAR 100		
Name	$\gamma$		AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Energy OE	0.00	4.92E-02	6.87E-03	1.26E-02	7.27E-02	1.49E-02	1.25E-02	5.34E-02	6.87E-03	6.87E-03	1.36E-01
Balanced Energy OE	0.10	3.80E-02	5.77E-03	1.63E-02	1.27E-01	1.34E-02	9.57E-03	4.35E-02	3.73E-03	3.73E-03	6.90E-02
	0.25	3.72E-02	9.43E-03	2.67E-02	1.34E-01	1.71E-02	1.73E-02	4.76E-02	5.77E-03	1.11E-02	7.86E-02
	0.50	4.74E-02	6.87E-03	4.20E-02	9.52E-02	1.80E-02	1.67E-02	7.24E-02	4.71E-03	1.61E-02	9.99E-02
	0.75	5.70E-02	9.43E-03	5.27E-02	1.56E-01	1.57E-02	1.57E-02	1.25E-01	1.11E-02	2.06E-02	2.15E-01
	1.00	6.52E-02	1.12E-02	4.56E-02	1.39E-01	1.71E-02	2.81E-02	1.66E-01	6.87E-03	1.95E-02	2.36E-01
	1.25	8.08E-02	2.48E-02	4.15E-02	1.65E-01	5.19E-02	4.11E-02	2.43E-01	1.70E-02	1.80E-02	1.47E-01
Inv-Balanced Energy OE	-0.75	2.49E-02	1.34E-02	2.29E-02	1.34E-01	3.02E-02	1.50E-02	1.26E-01	0.00E+00	6.87E-03	1.05E-01

(a)

Method	Tiny ImageNet			LSUN			Place365			Average		
$\gamma$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
0.00	5.00E-03	7.45E-03	5.89E-02	6.87E-03	6.87E-03	6.09E-02	5.77E-03	3.73E-03	6.59E-02	7.72E-03	8.33E-03	7.46E-02
0.10	7.45E-03	6.87E-03	1.10E-01	3.73E-03	7.45E-03	8.56E-02	4.71E-03	3.73E-03	8.64E-02	6.47E-03	7.95E-03	8.69E-02
0.25	3.73E-03	8.98E-03	7.39E-02	6.87E-03	1.60E-02	5.44E-02	0.00E+00	5.00E-03	4.53E-02	7.15E-03	1.42E-02	7.22E-02
0.50	7.64E-03	2.13E-02	5.25E-02	3.73E-03	1.71E-02	5.87E-02	6.87E-03	7.45E-03	6.38E-02	7.97E-03	2.01E-02	7.38E-02
0.75	4.71E-03	6.87E-03	1.30E-01	6.87E-03	1.53E-02	7.74E-02	6.87E-03	4.71E-03	1.13E-01	9.11E-03	1.93E-02	1.36E-01
1.00	1.26E-02	2.49E-02	1.65E-01	1.07E-02	2.11E-02	1.08E-01	1.11E-02	9.43E-03	7.04E-02	1.16E-02	2.48E-02	1.48E-01
1.25	1.25E-02	1.29E-02	1.93E-01	1.37E-02	2.54E-02	9.66E-02	3.73E-03	5.00E-03	9.37E-02	2.06E-02	2.40E-02	1.56E-01
-0.75	5.77E-03	6.87E-03	7.06E-02	7.45E-03	1.86E-02	1.05E-01	5.77E-03	5.00E-03	5.93E-02	1.04E-02	1.25E-02	1.00E-01

(b)

### WideResNet model on CIFAR100-LT:

Table S.15. Detailed evaluation result on CIFAR100-LT depending on  $\gamma$ : OOD detection performance (AUROC, AP, FPR) and classification accuracy (ACC) with model WideResNet(WRN-40-2); Mean over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR10; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365; N/A: not available because of unstable neural networks training

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Table S.16. Detailed evaluation result on CIFAR100-LT depending on  $\gamma$ : OOD detection performance (AUROC, AP, FPR) and classification accuracy (ACC) with model WideResNet(WRN-40-2); Std over six random runs are reported; (a): ACC and result on Texture, SVHN, and CIFAR10; (b): Total average result and result on Tiny Imagenet, LSUN, and Place365; N/A: not available because of unstable neural networks training

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### S.5.3 Image Classification

#### ResNet18 model on CIFAR10:

Table S.17. Evaluation result on CIFAR10 using ResNet18 : OOD detection performance with AUROC,AP and FPR; Mean over six random runs are reported(OE,EnergyOE,Ours).

Dataset	Method	AUC↑	AP↑	FPR↓
Texture	OE (tune)	97.90	96.41	11.67
	EnergyOE (tune)	98.88	<b>98.13</b>	5.94
	<b>Ours</b>	<b>98.90</b>	98.01	<b>5.65</b>
SVHN	OE (tune)	98.67	99.44	7.10
	EnergyOE (tune)	98.88	99.57	6.51
	<b>Ours</b>	<b>98.97</b>	<b>99.60</b>	<b>5.68</b>
CIFAR100	OE (tune)	92.07	91.39	<b>31.05</b>
	EnergyOE (tune)	<b>92.61</b>	<b>92.76</b>	34.41
	<b>Ours</b>	92.54	92.64	34.27
Tiny ImageNet	OE (tune)	93.17	90.36	25.39
	EnergyOE (tune)	<b>94.61</b>	<b>92.76</b>	<b>22.79</b>
	<b>Ours</b>	94.59	92.68	23.56
LSUN	OE (tune)	96.63	96.25	15.22
	EnergyOE (tune)	98.34	98.16	7.33
	<b>Ours</b>	<b>98.50</b>	<b>98.23</b>	<b>6.60</b>
Places365	OE (tune)	95.63	98.31	18.80
	EnergyOE (tune)	97.31	98.98	11.97
	<b>Ours</b>	<b>97.47</b>	<b>99.01</b>	<b>11.28</b>
Average	OE (tune)	95.68	95.36	18.20
	EnergyOE (tune)	96.77	<b>96.72</b>	14.82
	<b>Ours</b>	<b>96.83</b>	96.70	<b>14.51</b>

Table S.18. Evaluation result on CIFAR10 using ResNet18 : OOD detection performance with AUROC,AP and FPR; Std over six random runs are reported(OE,EnergyOE,Ours).

Dataset	Method	AUC↑	AP↑	FPR↓
Texture	OE (tune)	1.42E-14	1.42E-14	1.77E-02
	EnergyOE (tune)	4.71E-03	6.87E-03	4.08E-02
	<b>Ours</b>	6.87E-03	1.00E-02	6.79E-02
SVHN	OE (tune)	0.00E+00	0.00E+00	3.73E-03
	EnergyOE (tune)	1.49E-02	5.00E-03	9.84E-02
	<b>Ours</b>	2.38E-02	8.98E-03	1.69E-01
CIFAR100	OE (tune)	0.00E+00	0.00E+00	2.03E-02
	EnergyOE (tune)	8.98E-03	5.00E-03	1.23E-01
	<b>Ours</b>	8.98E-03	9.57E-03	5.40E-02
Tiny ImageNet	OE (tune)	0.00E+00	0.00E+00	7.64E-03
	EnergyOE (tune)	3.73E-03	3.73E-03	7.56E-02
	<b>Ours</b>	6.87E-03	5.77E-03	7.65E-02
LSUN	OE (tune)	0.00E+00	0.00E+00	6.87E-03
	EnergyOE (tune)	7.45E-03	7.64E-03	4.28E-02
	<b>Ours</b>	5.00E-03	4.71E-03	6.99E-02
Places365	OE (tune)	0.00E+00	0.00E+00	7.45E-03
	EnergyOE (tune)	6.87E-03	0.00E+00	1.57E-02
	<b>Ours</b>	3.73E-03	3.73E-03	4.82E-02
Average	OE (tune)	2.37E-15	8.33E-04	1.15E-02
	EnergyOE (tune)	3.44E-03	2.62E-03	3.21E-02
	<b>Ours</b>	3.30E-03	3.52E-03	2.86E-02



**ResNet18 model on CIFAR100:**

Table S.19. Evaluation result on CIFAR100 using ResNet18 : OOD detection performance with AUROC,AP and FPR; Mean over six random runs are reported(OE,EnergyOE,Ours).

Dataset	Method	AUC↑	AP↑	FPR↓
Texture	OE (tune)	83.69	71.62	50.41
	EnergyOE (tune)	89.03	80.83	38.02
	<b>Ours</b>	<b>89.11</b>	<b>80.94</b>	<b>37.78</b>
SVHN	OE (tune)	85.15	91.45	45.70
	EnergyOE (tune)	93.14	96.19	23.22
	<b>Ours</b>	<b>93.41</b>	<b>96.33</b>	<b>22.48</b>
CIFAR10	OE (tune)	<b>75.52</b>	<b>70.46</b>	63.52
	EnergyOE (tune)	74.96	69.20	<b>62.83</b>
	<b>Ours</b>	74.70	68.74	63.43
Tiny ImageNet	OE (tune)	79.67	65.58	<b>57.13</b>
	EnergyOE (tune)	<b>80.48</b>	<b>67.74</b>	58.15
	<b>Ours</b>	80.36	67.56	58.61
LSUN	OE (tune)	86.11	75.38	46.25
	EnergyOE (tune)	88.26	<b>77.72</b>	38.34
	<b>Ours</b>	<b>88.34</b>	77.68	<b>37.89</b>
Places365	OE (tune)	86.41	93.11	47.31
	EnergyOE (tune)	<b>89.19</b>	<b>94.27</b>	37.56
	<b>Ours</b>	89.17	94.22	<b>37.40</b>
Average	OE (tune)	82.76	77.93	51.72
	EnergyOE (tune)	85.84	<b>80.99</b>	43.02
	<b>Ours</b>	<b>85.85</b>	80.91	<b>42.93</b>

Table S.20. Evaluation result on CIFAR100 using ResNet18 : OOD detection performance with AUROC,AP and FPR; Std over six random runs are reported(OE,EnergyOE,Ours).

Dataset	Method	AUC↑	AP↑	FPR↓
Texture	OE (tune)	0.00E+00	4.71E-03	9.57E-03
	EnergyOE (tune)	6.87E-03	1.49E-02	1.16E-01
	<b>Ours</b>	1.21E-02	1.89E-02	1.29E-01
SVHN	OE (tune)	3.73E-03	0.00E+00	2.05E-02
	EnergyOE (tune)	8.98E-03	8.98E-03	3.13E-02
	<b>Ours</b>	1.98E-02	1.46E-02	1.23E-01
CIFAR10	OE (tune)	3.73E-03	3.73E-03	1.34E-02
	EnergyOE (tune)	9.57E-03	1.07E-02	6.44E-02
	<b>Ours</b>	7.64E-03	1.37E-02	6.50E-02
Tiny ImageNet	OE (tune)	0.00E+00	4.71E-03	2.11E-02
	EnergyOE (tune)	5.77E-03	1.00E-02	4.85E-02
	<b>Ours</b>	7.45E-03	9.57E-03	5.88E-02
LSUN	OE (tune)	0.00E+00	0.00E+00	1.83E-02
	EnergyOE (tune)	9.43E-03	1.25E-02	5.28E-02
	<b>Ours</b>	8.98E-03	1.34E-02	6.08E-02
Places365	OE (tune)	1.42E-14	0.00E+00	1.26E-02
	EnergyOE (tune)	5.00E-03	5.00E-03	1.67E-02
	<b>Ours</b>	5.77E-03	5.00E-03	2.21E-02
Average	OE (tune)	9.62E-04	1.60E-03	6.14E-03
	EnergyOE (tune)	3.42E-03	5.56E-03	2.43E-02
	<b>Ours</b>	4.04E-03	3.97E-03	1.41E-02

## S.6. Experiment Results on synthetic OOD dataset

### S.6.1 Long-tailed Image Classification

#### ResNet18 model on CIFAR10-LT:

Table S.21. Synthetic OOD evaluation result on CIFAR10-LT using ResNet18 : OOD detection performance with AUROC,AP and FPR; (a): Mean over six random runs; (b): Std over six random runs(OE,OECC,EnergyOE,Ours).

(a)					(b)				
Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Gaussian	OE (tune)	97.15	92.19	5.11	Gaussian	OE (tune)	1.46E-02	3.13E-02	5.25E-02
	OECC	<b>99.80</b>	<b>99.65</b>	0.50		OECC	3.73E-03	4.71E-03	5.00E-03
	EnergyOE (tune)	99.74	99.33	0.54		EnergyOE (tune)	6.87E-03	3.86E-02	1.77E-02
	<b>Ours</b>	99.76	99.16	<b>0.49</b>		<b>Ours</b>	7.45E-03	1.25E-02	3.73E-03
Rademacher	OE (tune)	<b>99.28</b>	98.24	1.57	Rademacher	OE (tune)	3.73E-03	1.29E-02	1.37E-02
	OECC	99.03	<b>98.36</b>	2.51		OECC	3.73E-03	1.34E-02	1.25E-02
	EnergyOE (tune)	99.13	97.16	1.51		EnergyOE (tune)	1.71E-02	4.73E-02	2.54E-02
	<b>Ours</b>	99.00	96.26	<b>1.42</b>		<b>Ours</b>	1.86E-02	6.37E-02	3.54E-02
Blob	OE (tune)	43.80	43.12	84.15	Blob	OE (tune)	1.16E-01	7.42E-02	1.88E-01
	OECC	59.18	52.12	73.19		OECC	2.70E-01	1.60E-01	3.05E-01
	EnergyOE (tune)	90.16	85.39	28.79		EnergyOE (tune)	6.57E-02	9.63E-02	3.64E-01
	<b>Ours</b>	<b>93.18</b>	<b>89.34</b>	<b>22.20</b>		<b>Ours</b>	1.14E-01	1.63E-01	3.56E-01
Average	OE (tune)	80.08	77.85	30.27	Average	OE (tune)	3.62E-02	2.10E-02	7.26E-02
	OECC	86.00	83.38	25.40		OECC	9.00E-02	5.68E-02	1.02E-01
	EnergyOE (tune)	96.34	93.96	10.28		EnergyOE (tune)	2.62E-02	5.10E-02	1.20E-01
	<b>Ours</b>	<b>97.32</b>	<b>94.92</b>	<b>8.04</b>		<b>Ours</b>	3.65E-02	5.26E-02	1.26E-01

#### ResNet18 model on CIFAR100-LT:

Table S.22. Synthetic OOD evaluation result on CIFAR100-LT using ResNet18 : OOD detection performance with AUROC,AP and FPR; (a): Mean over six random runs; (b): Std over six random runs(OE,OECC,EnergyOE,Ours).

(a)					(b)				
Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Gaussian	OE (tune)	56.27	48.35	69.79	Gaussian	OE (tune)	2.05E-01	1.22E-01	2.16E-01
	OECC	<b>95.59</b>	87.82	<b>6.58</b>		OECC	4.34E-02	1.16E-01	3.53E-02
	EnergyOE (tune)	88.13	79.36	27.89		EnergyOE (tune)	1.59E-01	2.77E-01	2.54E-01
	<b>Ours</b>	94.56	<b>88.32</b>	13.22		<b>Ours</b>	1.10E-01	1.91E-01	2.09E-01
Rademacher	OE (tune)	48.47	44.24	75.03	Rademacher	OE (tune)	1.28E-01	6.03E-02	1.72E-01
	OECC	<b>92.11</b>	80.92	<b>11.78</b>		OECC	2.62E-02	5.16E-02	5.21E-02
	EnergyOE (tune)	83.43	71.56	32.76		EnergyOE (tune)	2.05E-01	2.77E-01	3.80E-01
	<b>Ours</b>	91.48	<b>82.87</b>	18.42		<b>Ours</b>	1.67E-01	2.48E-01	3.22E-01
Blob	OE (tune)	70.43	66.45	73.39	Blob	OE (tune)	9.75E-02	1.26E-01	2.06E-01
	OECC	95.42	90.91	<b>12.25</b>		OECC	2.31E-02	7.13E-02	1.53E-01
	EnergyOE (tune)	88.48	85.37	36.28		EnergyOE (tune)	8.50E-02	8.30E-02	4.39E-01
	<b>Ours</b>	<b>96.42</b>	<b>94.92</b>	13.30		<b>Ours</b>	5.88E-02	7.65E-02	3.79E-01
Average	OE (tune)	58.39	53.01	72.74	Average	OE (tune)	7.97E-02	6.57E-02	1.16E-01
	OECC	<b>94.37</b>	86.55	<b>10.20</b>		OECC	2.17E-02	5.23E-02	6.18E-02
	EnergyOE (tune)	86.68	78.76	32.31		EnergyOE (tune)	1.02E-01	1.68E-01	6.82E-02
	<b>Ours</b>	94.15	<b>88.70</b>	14.98		<b>Ours</b>	9.25E-02	1.43E-01	1.39E-01

## S.6.2 Image Classification

### ResNet18 model on CIFAR10:

Table S.23. Synthetic OOD evaluation result on CIFAR10 using ResNet18 : OOD detection performance with AUROC,AP and FPR; (a): Mean over six random runs; (b): Std over six random runs(OE,OECC,EnergyOE,Ours).

(a)					(b)				
Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Gaussian	OE (tune)	99.74	<b>99.28</b>	0.57	Gaussian	OE (tune)	0.00E+00	4.71E-03	0.00E+00
	OECC	99.43	98.20	0.80		OECC	2.40E-01	1.02E+00	2.33E-01
	EnergyOE (tune)	99.76	99.19	0.49		EnergyOE (tune)	5.77E-03	1.77E-02	9.57E-03
	<b>Ours</b>	<b>99.82</b>	99.20	<b>0.28</b>		<b>Ours</b>	3.73E-03	1.80E-02	7.45E-03
Rademacher	OE (tune)	99.63	98.91	0.80	Rademacher	OE (tune)	4.71E-03	7.45E-03	1.21E-02
	OECC	99.56	98.47	0.57		OECC	2.79E-01	1.17E+00	2.90E-01
	EnergyOE (tune)	99.59	98.57	0.72		EnergyOE (tune)	1.61E-02	6.67E-02	3.16E-02
	<b>Ours</b>	<b>99.78</b>	<b>98.93</b>	<b>0.33</b>		<b>Ours</b>	4.71E-03	1.70E-02	8.16E-03
Blob	OE (tune)	97.71	96.71	8.84	Blob	OE (tune)	2.75E-02	3.04E-02	2.49E-01
	OECC	99.40	98.69	1.50		OECC	1.11E-01	4.37E-01	8.98E-02
	EnergyOE (tune)	99.42	99.24	2.10		EnergyOE (tune)	1.57E-02	1.57E-02	6.47E-02
	<b>Ours</b>	<b>99.63</b>	<b>99.47</b>	<b>1.44</b>		<b>Ours</b>	1.80E-02	1.73E-02	5.30E-02
Average	OE (tune)	99.03	98.30	3.41	Average	OE (tune)	8.61E-03	9.57E-03	8.08E-02
	OECC	99.46	98.45	0.96		OECC	1.95E-01	8.50E-01	1.96E-01
	EnergyOE (tune)	99.59	99.00	1.10		EnergyOE (tune)	1.10E-02	3.07E-02	2.94E-02
	<b>Ours</b>	<b>99.74</b>	<b>99.20</b>	<b>0.69</b>		<b>Ours</b>	6.31E-03	1.23E-02	1.91E-02

### ResNet18 model on CIFAR100:

Table S.24. Synthetic OOD evaluation result on CIFAR100 using ResNet18 : OOD detection performance with AUROC,AP and FPR; (a): Mean over six random runs; (b): Std over six random runs(OE,OECC,EnergyOE,Ours).

(a)					(b)				
Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$	Dataset	Method	AUC $\uparrow$	AP $\uparrow$	FPR $\downarrow$
Gaussian	OE (tune)	81.41	66.42	25.99	Gaussian	OE (tune)	3.27E-02	3.44E-02	1.18E-01
	OECC	<b>99.31</b>	<b>98.59</b>	<b>1.82</b>		OECC	5.06E-02	1.46E-01	1.09E-01
	EnergyOE (tune)	92.66	83.22	12.77		EnergyOE (tune)	1.17E-01	2.20E-01	1.27E-01
	<b>Ours</b>	93.92	85.64	11.01		<b>Ours</b>	7.08E-02	1.42E-01	1.08E-01
Rademacher	OE (tune)	99.87	99.72	0.33	Rademacher	OE (tune)	0.00E+00	3.73E-03	4.71E-03
	OECC	96.44	89.06	4.58		OECC	1.35E-01	3.89E-01	1.14E-01
	EnergyOE (tune)	<b>99.91</b>	<b>99.83</b>	<b>0.21</b>		EnergyOE (tune)	3.73E-03	9.43E-03	6.87E-03
	<b>Ours</b>	<b>99.91</b>	<b>99.83</b>	<b>0.21</b>		<b>Ours</b>	4.71E-03	6.87E-03	7.64E-03
Blob	OE (tune)	98.31	97.81	6.52	Blob	OE (tune)	2.92E-02	3.98E-02	1.55E-01
	OECC	94.26	89.72	14.67		OECC	1.99E-01	3.20E-01	6.57E-01
	EnergyOE (tune)	98.56	98.07	6.01		EnergyOE (tune)	3.40E-02	3.98E-02	1.78E-01
	<b>Ours</b>	<b>98.75</b>	<b>98.34</b>	<b>5.24</b>		<b>Ours</b>	1.57E-02	2.27E-02	8.03E-02
Average	OE (tune)	93.20	87.98	10.94	Average	OE (tune)	1.56E-02	2.03E-02	6.29E-02
	OECC	96.67	92.46	7.02		OECC	8.80E-02	1.79E-01	2.49E-01
	EnergyOE (tune)	97.04	93.71	6.33		EnergyOE (tune)	4.55E-02	8.38E-02	8.44E-02
	<b>Ours</b>	<b>97.53</b>	<b>94.60</b>	<b>5.49</b>		<b>Ours</b>	2.22E-02	4.53E-02	4.59E-02